INDUSTRIAL RESEARCH

DECEMBER 1961

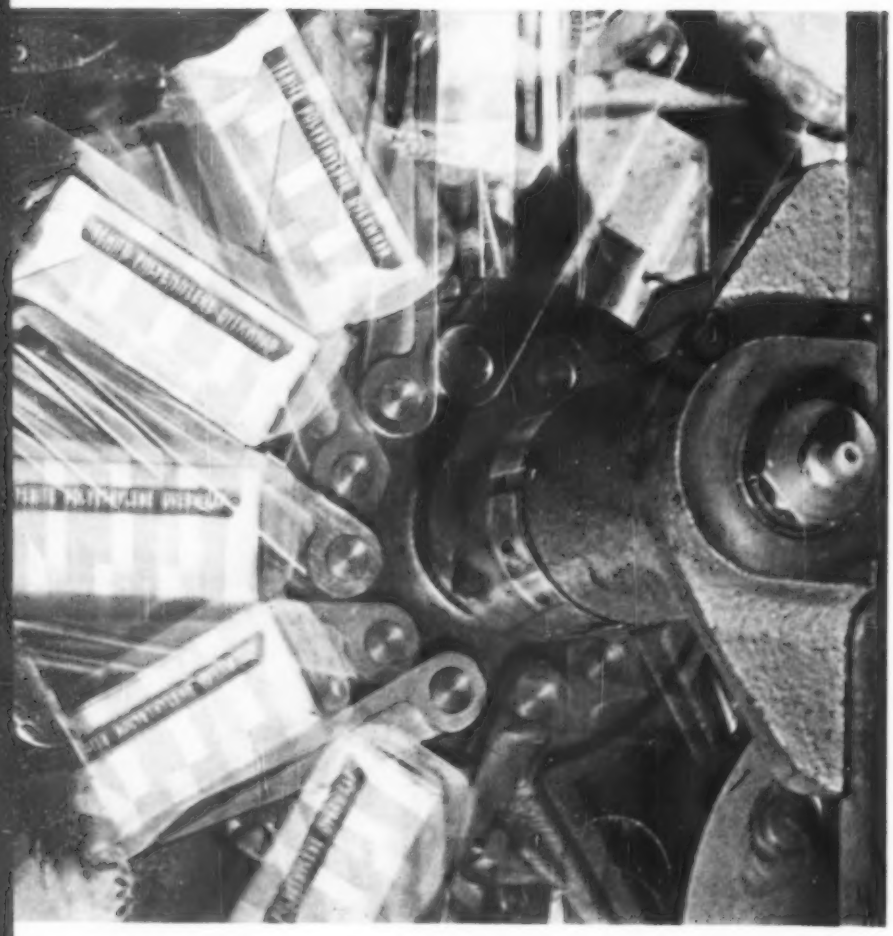
one dollar

HOW TO GET GOVERNMENT R&D CONTRACTS

THE TECHNICAL MAGAZINE FOR MANAGEMENT

The interplay of plastics and packaging

A complex of technology and art, packaging has gained from the versatility of plastics. The adaptation of Tenite plastics to packaging functions holds promise for improvements in other product fields.



The egg and the coconut, cited in offhand discussions as being ideally packaged for their environments, seem ill-fitted to the complicated methods of modern distribution. The eggshell, unfortunately, can do little more than hold the egg together in the nest. And the coconut, for all its ability to float across the sea to a friendly beach, might be improved by a tear-tape.

A package today must perform several functions beyond mere containment—one reason why plastics have become so popular with package designers. Man-made, plastics can also be man-tailored. For example, Eastman's laboratory has developed twenty-six formulations of Tenite Polyethylene for extrusion into packaging film alone, combining such variables as stiffness, gloss, transparency, and the ability to be heat-sealed on high-speed machines.

Protecting the packaged contents is an obvious essential, and plastics perform some remarkable protective functions. A hypodermic needle in a molded polyethylene container stays both sterile and sharp in its heat-sealed package, which also holds the needle firmly to protect against impact damage [1]. Since polyethylene is impervious to moisture vapor, a polyethylene coating on paper will protect frozen foods from "freezer burn" caused by loss of moisture. Some products even need protection from their packages. For example, the multi-wall paper bags Eastman uses for shipping polyethylene have an inner coating of Tenite Polyethylene to prevent contamination of the product by paper fibers [2].

Packaging for movement and storage is a step beyond protection, and here the light weight of plastics is important. Polyethylene, for years the lightest solid plastic (it floats on water), has yielded in this respect to polypropylene. Drums for chemicals are molded of Tenite Polyethylene not only because it is highly inert and withstands impact, but because the light weight

means shipping economy [3]. Special formulations of both Tenite Polyethylene and Tenite Polypropylene resist stress-cracking, a phenomenon occurring when a material is under stress in the presence of a chemical that normally does not affect it. Tenite Polypropylene shows remarkable resistance to repeated flexing. Because laboratory test bars have been flexed over a million times without cracking, it is said to have a "built-in hinge."

Even the preparation of food servings has come within the purview of plastic packaging. The heat resistance of Tenite Polypropylene suggests its use as film for the boilable cook-in pouch. Another Eastman plastic, Tenite Polyester, is made into a film bag in which corn, oil, and salt are sealed, to be popped later under three minutes of heat from infra-red lamps.

The mechanics of packaging challenge any material, and the adaptability of plastics is a special virtue. In fact, their capabilities have helped advance package design, as in the case of blister packaging—plastic sheet thermoformed to fit the contents and attached to a cardboard backing. With Tenite Acetate, Eastman helped to pioneer this packaging method, which also employs Tenite Butyrate and Tenite Propionate today.

All together, Tenite plastics include formulations to be molded, extruded, or applied as coatings to other packaging materials; to be printed, heat-sealed, or laminated. Where color is important, Eastman can supply over 42,000 colors and effects from its color laboratory [4]. And along with all their other advantages, these plastics have proved economical—a governing factor in the acceptance of a material in the packaging field.

Continuously adapting Tenite plastics to the shifting technology of packaging has given Eastman a fund of information and materials useful in the design of other products. Thus, the stress-cracking resistance of polyethylene makes it practical for pipe to convey chemicals; the moisture resistance of polyethylene led to its use in coating burlap for Army Ordnance huts ments to protect stored equipment; the easy formability of sheet of Butyrate makes it practical for a miniature planetarium [5]

We'll be glad to show you how the people at Eastman, with ingenuity and experience, can make plastics fit your ideas for product improvements or new developments. And for a comprehensive picture of Tenite plastics in packaging, get the 20-page booklet "TENITE PLASTICS VIEWS—PACKAGING" by writing to EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

1

2

3

4

5

TENITE®

ACETATE • BUTYRATE
PROPIONATE • POLYETHYLENE
POLYPROPYLENE • POLYESTER

Adaptable plastics by Eastman

Industrial Research is dedicated to reducing the time lag between invention and production. It seeks to do this by informing technical management of new scientific developments and their profitable applications in all fields of industry.

INDUSTRIAL RESEARCH
BEVERLY SHORES, INDIANA

Subscriptions: $7 for one year (12 issues); $12 for two years; $15 for three years, to United States; $2 extra for each 12 issues to foreign countries and Canada. Foreign remittance by International Money Order payable at Chicago, Ill., U.S.A. When changing address, please notify Circulation Dept. at address above. Notification of changes of job title are requested.

Advertising: I•R accepts 1, 2, 3, and 4-color ads, either offset or letterpress. Inserts, special paper stocks, die-cuts are available. Rate and data card is available to qualified advertisers and agencies.

Editorial: Professional science writers, industrial executives, research workers, educators, artists, and photographers are invited to query the editor at address above, with ideas for articles or art. Do not send manuscripts without query. Answers to queries are prompt.

Reproduction prohibited without permission. Address the editor for permission to reprint articles.

Copyright© 1961, by INDUSTRIAL RESEARCH INC.

THE COVER, *painted by I•R art director Tom Schmerler, depicts the ever-widening pattern of the big, powerful, often-paternal Pentagon. It illustrates the feature article in this issue, "How to Get Government R&D Contracts," a sequel to last month's "Can You Afford Government R&D Contracts?"* ◂ *If you can afford it, entering the concentric five-sided maze is great sport. You won't make much money directly, but secondary advantages include improving your corporate reputation, building a sound R&D division, and turning "swords into plowshares"—all worthy and ultimately profitable lures.* ◂ *A second government article is included in this issue. "Should the Government Back More Basic Research?" is queried by Secretary of Commerce Luther H. Hodges. He notes that 300 firms do 90% of all research, that the government needs to "seed" commercial applications, that government—as industry—is having difficulty finding or building good technical management, and that government's clashes with industry over expansion of government activities in these fields are unnecessary. You'll want to form your own opinions about Hodges' views.* ◂ *New applications of significant research into gas turbines, the unique metal columbium, and the thermal energy of the sea also are told in this edition by several authorities.*

SELLING TO THE PENTAGON

52,000 copies of this issue printed. Circulation audited and verified by VAC. Industrial Research also has applied for an audit with BPA for the six-month period ending this issue, December 1961.

DECEMBER 1961

INDUSTRIAL RESEARCH

THE TECHNICAL MAGAZINE FOR MANAGEMENT

editor & publisher, Neil P. Ruzic

managing editor, Anthony G. Baker
art director, Tom Schmerler
staff editors and consultants, M. M. Wyatt
Dr. H. L. Garbarino
Walter Esse
Dr. R. W. Benson
Daniel J. Fink
Rudolf G. Hentschel
Harold M. Kimball
Dr. Walter C. McCrone
Richard L. Moore
Dr. Joseph M. Still
Leonard M. Taussig
Seaton Preston
Dr. Robert Pasek

editorial assistants, J. D. Howard
S. A. Garry
R. M. Parker
general manager, I. D. Canton
circulation manager, H. A. Bratkovic
marketing manager, Joseph F. Ryan

ADVERTISING SALES OFFICES
(see page 50)

EDITORIAL ADVISORY BOARD
Dr. Howard Aiken
Isaac L. Auerbach
Dr. Richard Bellman
Rear Adm. Rawson Bennett
Dr. Cledo Brunetti
Marvin Camras
Dr. W. L. Everitt
Dr. L. Kermit Herndon
Dr. Thomas J. Higgins
DeWitt O'Kelly Myatt
Dr. Harlow Shapley
Dr. M. A. Tuve
Sir Robert Watson-Watt
Dr. Clyde E. Williams
Dr. V. K. Zworykin

the 16th issue of I·R

16

INDUSTRIAL RESEARCH: *editorial, circulation, and advertising offices, Beverly Shores, Ind. Vol. 3, No. 6, December, 1961, published monthly by Industrial Research Inc.*
(Copyright© 1961).
Copies of I·R on microfilm are available from University Microfilms, 313 N. First St., Ann Arbor, Mich. (See page 4 for subscription and other information.)

ARTICLES

how to get government R&D contracts . . 13
A good technical staff almost sells itself; yet some simple guides to dealing with the government and an awareness of the changing face of warfare may help your firm get its slice of federal pie.
by Dr. Theodore K. Steele, executive vice-president, Bulova Research & Development Laboratories

should the government back more basic research? 20
If the government expects to be in the business of scientific innovation five years from now, it must encourage basic research and seed commercial application.
by Luther H. Hodges, Secretary of Commerce

the controversial gas turbine 29
New developments are grooming gas turbines as auxiliary units for power generation, midget jets for light planes, and as power plants for automobiles and medium-sized ships.
by Dr. R. A. Budenholzer, director, American Power Conference

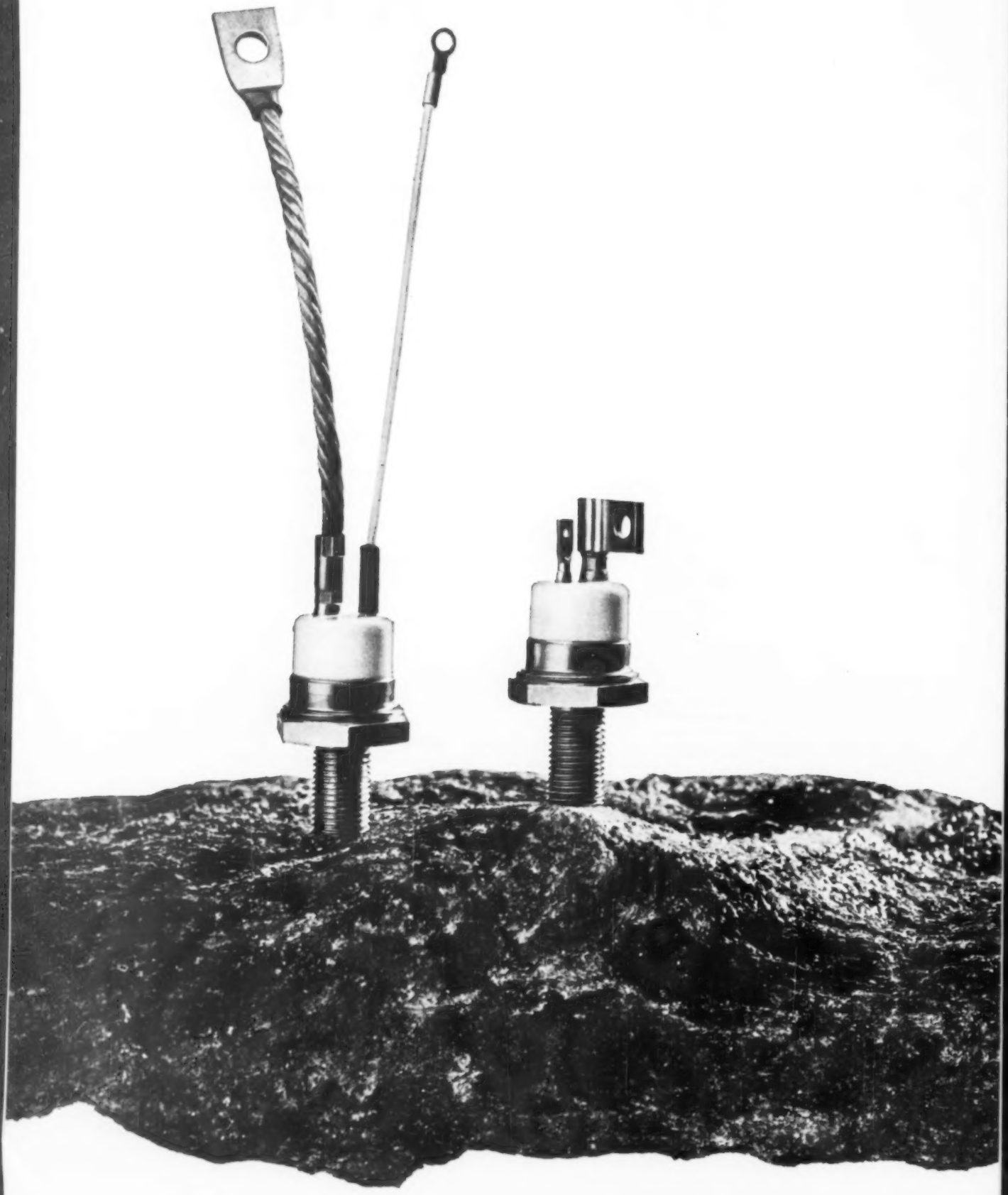
thermal energy of the sea 36
The temperature difference between the surface and depths of the oceans can be utilized for almost unlimited amounts of energy.
by Asa E. Snyder, vice-president, Pratt & Whitney Co. Inc.

industrial applications of the exotic metal columbium 42
A major potential for columbium lies in columbium-bearing steel. But pure columbium is finding use in the electronics, nuclear, construction, and other industries.
by Marx Hirsch, president, Molybdenum Corp. of America

DEPARTMENTS

feedback from technical management 8
the research trendletter 25
the I-R dictionary for technical management 28
ideas and applications 33-34
advertising index 50
employment clearinghouse 51
checklist for more information 52
annual editorial index 53

SEMICONDUCTOR NEWS: FROM WESTINGHOUSE AT YOUNGWOOD



Westinghouse announces new 70-amp ratings in "Rock-Top" Trinistor® controlled rectifiers

Highest rated flag type in the industry. Type 809 Trinistor controlled rectifier series, in both flag terminal and flexible lead types, now immediately available in production quantities at 70-amp ratings! Exclusive Westinghouse "Rock-Top" construction offers superior electrical and mechanical characteristics for greater reliability under all operating conditions. Provides positive protection against arcing at highest voltages. Exclusive new flag terminal design has lower weight, requires less headroom. Outstanding parameters include: ▪ 70-amp average forward current at 180° C. conduction ▪ maximum rating of 110 amperes D.C. ▪ 600 nanosecond switching time ▪ efficiencies in excess of 98% ▪ minimum noise level ▪ peak reverse voltages to 480 volts ▪ ideal parameters for high-speed static switch functions.

Industrial, commercial, and military applications include: high-frequency power generation; variable frequency controls; pulse generation; ignitron firing; welding control. Trinistors also replace thyratrons, contactors, magnetic amplifiers, relays.

For more information, or technical assistance, contact your nearest Westinghouse representative, or write: Westinghouse Electric Corporation, Semiconductor Department, Youngwood, Penna. *You can be sure... if it's Westinghouse.* SC-1046

For Immediate "Off-The-Shelf" Delivery, Order From These Westinghouse Distributors:

EASTERN

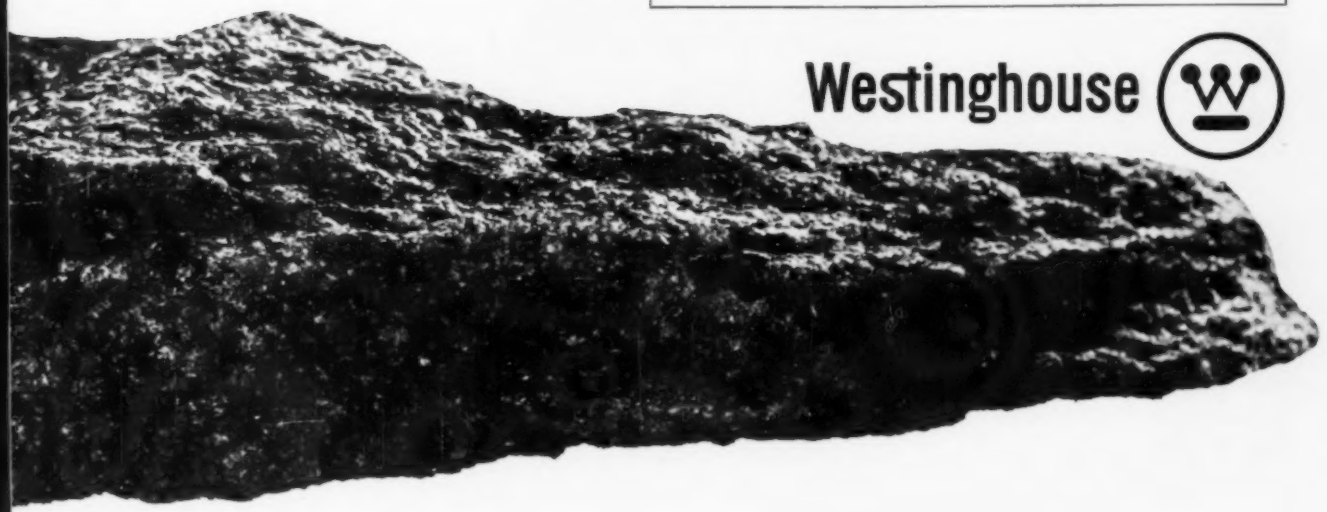
ACK SEMICONDUCTOR, INC. Birmingham 5, Ala./FA 2-0588
CAMERADIO Pittsburgh, Pa./EX 1-4000
CRAMER ELECTRONICS, INC. Boston, Mass./CO 7-4700
ELECTRONIC WHOLESALERS, INC. Melbourne, Florida/PA 3-1441
GENERAL RADIO SUPPLY CO., INC. Camden, N. J./WO 4-8560
GENESEE RADIO PARTS CO. Buffalo, N. Y./TR 3-9661
KANN-ELLERT ELECTRONICS, INC. Baltimore, Md./TU 9-4242
MILGRAY ELECTRONICS New York, N. Y./RE 2-4400
RADIO & ELECTRONIC PARTS CORP. Cleveland, Ohio/UT 1-6060
SCHWEBER ELECTRONICS Long Island, N. Y./PI 6-6520 Silver Spring, Md./JU 5-7023

MIDWESTERN

E.C.I. SEMICONDUCTORS, INC. Kansas City, Mo./WE 1-0829
ELECTRONIC COMPONENTS FOR INDUSTRY CO. St. Louis, Mo./WO 2-9916
HALLMARK INSTRUMENTS CORP. Dallas, Texas/RI 7-8933
INTER-STATE RADIO & SUPPLY CO. Denver 4, Colo./TA 5-8257
LENERT CO. Houston, Texas/CA 4-7663
MIDLAND SPECIALTY CO. El Paso, Texas/KE 3-9555 Phoenix, Ariz./AL 8-8254 Albuquerque, N. M./CH 7-0236
RADIO DISTRIB. CO. Indianapolis, Ind./ME 7-5571
SEMICONDUCTOR SPEC., INC. Chicago, Ill./NA 2-8860
S. STERLING CO. Detroit, Mich./BR 3-2900
UNITED RADIO, INC. Cincinnati, Ohio/MA 1-6530

WESTERN

ALMAC ELECTRONICS CORP. Seattle, Wash./PA 3-7310
ELMAR ELECTRONICS Oakland, Cal./TE 4-3311
HAMILTON ELECTRO SLS. Los Angeles, Cal./BR 2-9154 Palo Alto, Cal./DA 1-7541
NEWARK ELECTRONICS CO. Inglewood, Cal./OR 4-8440



Westinghouse

I·R FEEDBACK *from technical management*

Of men and machines

Sir:

Arthur Clarke, in his article "The Evolutionary Cycle from Man to Machine" (November), has done his usual excellent job of a clear and interesting presentation. The British seem to average better on this than many of us in the United States.

I do wish, however, that he had mentioned the contributions of Dr. W. Ross Ashby (another Britisher). To my mind, he is both a pioneer in postulating possible mechanisms for learning and is too little known.

J. Frank Coneybear
President
Astra Inc.

(I·R did its bit to bring Dr. Ashby's major work, "Design for a Brain," to the attention of its readers in the article, "Automata," in 1959, Vol. 1, No. 2, pages 46 to 59.)

Russian Submarines

Sir:

I do not suggest that our space program should be whittled down, but I ask that we consider for a moment the hypothesis that the next war will be won not in outer space but on the bottom of the sea. The Russians boast about their missiles and their 100 megaton bombs; they are very quiet about their submarines. They make a lot of noise about their men in space; they are very modest about an effort in oceanography several times as large as ours. What a brilliant military exploit it would be to send us off to the moon, while they seize the ocean. By some logic I have never been able to understand, it has been asserted that the power that controls the moon can conquer the earth. I think we might add to this that the power that controls the oceans can control the power that governs the moon.

Dr. B. D. Thomas
President
Battelle Memorial Inst.

Living in space

Sir:

I have read with pleasure Mr. Whisenhunt's article "Living in Space" (Vol. 3, No. 3). If anything, the author is quite conservative in his estimates of systems weights versus time. Our assessment of the present state-of-the-art would indicate that the systems weights, and hence the cross-over time for the regions of application of the various systems (open, semi-closed, and closed), might well be reduced.

I might say that I have read with pleasure this issue of *Industrial Research*. I should like to add my congratulations to the many that you undoubtedly have received on the choice of an editorial advisory board that certainly is one of the broadest-ranging and honored I have seen on any technical magazine.

Leo Steg
Manager, Space Sciences Lab.
General Electric Co.

Ad infinitum

Sir:

In reference to the letter in I·R feedback (page 16, June-July 1961), which in turn refers to a cartoon (reprinted with the above referred-to letter) published in an earlier issue, I feel compelled to indulge myself in accordance with the penchant mathematicians have for stating general formulae which subsume entire classes of important problems.

Your correspondent's designation "antiantimissilemissilemissile" is the specific name of the third generation missile. The general formula for the entire family of missiles, antimissile missiles, and the succeeding generations of countering weapons can be derived by considering the name of the forebears of the third generation and the name of the as yet unborn (?) fourth generation. Thus:

Name	*Generation*
missile	first
antimissilemissile	second
antiantimissilemissilemissile	third
antiantiantimissile-missilemissilemissile	fourth

From the above, it can be seen that the next generation is specified by prefixing an "anti" and adding a "missile" to the name of its predecessor. Also, since a specific generation in the missile family is indicated by the number of repetitions of the family name, any desired generation can be designated readily by writing repeatedly the word "missile" as many times as the number of the desired generation indicates and preceding this series with one less repetition of the prefix "anti."

Hence, if A equals anti, M equals missile, and n takes on values 0, 1, 2, 3, . . . ad infinitum, the general formula is:

$$A^n M^{n+1}$$

I might add that in happier times (ah, long lost youth) we generated similar formulae related to our cumulative reflections as seen in mirrors on opposite walls of the barber shop, related to boxes of breakfast cereal on which was displayed a picture of a child holding a box of breakfast cereal on which was displayed . . .

However, to borrow from the French, *c'est la guerre!*

Arnold A. Heyl
Operations Officer
Human Resources Research Office
George Washington University

File at Random . . . Find at Once!

Acme Electrofile ends refiling. You can do it blindfolded! Misfiling is impossible. Push-button "recall" spots the card you want.

Think of the time and money saved in billing, research, customer service, personnel records, hundreds of other uses. To speed up your operation with push-button record-keeping send coupon today.

Just touch the keyboard. Electrofile automatically selects a card—or group of cards. Code by name, number or subject—even phase of subject.

ACME VISIBLE

ACME VISIBLE RECORDS, Inc.
9412 West Allview Drive, Crozet, Va.

Please let me have full facts on Acme Electrofile, and why it is today's most advanced filing concept.

NAME _____ TITLE _____

ADDRESS _____

CITY _____ ZONE ____ STATE _____

Energy conversion

Sir:

Your table of contents in the October *Industrial Research* reads like the new course-list of the nation's leading universities. My compliments to you for giving all the energy conversion techniques equal time.

Your article, "Thermoelectricity," certainly covered the field well, particularly the business prospects. From the scientific point of view, I think the amazing thing about thermoelectricity is the fact that it is possible to have an electric current without a voltage potential or to have heat transfer without a temperature differential.

Also, it is ironical that even though thermoelectric effects were observed over 100 years ago, their full significance was not realized and the subject lay dormant for many decades. The main part of the research in this field has been performed only in recent years.

William F. Brown
Iowa State University

Sir:

Congratulations on a splendid (Energy Conversion) edition. Subject matter, layout, and general tone of the book are such that only admiration can be the reader's reaction. This is bound to accelerate interest in the subject of energy conversion everywhere.

Arthur F. Joy
Technical Specialist
Raytheon Co.

Sir:

We congratulate you on a very successful issue covering energy conversion. Will you send us 25 copies for our company seminar.

Frank Melanson
Manager, Market Planning Dept.
Minneapolis-Honeywell Regulator Co.

Sir:

The article on "Solar Machines in Space" is extremely well written, interesting, and an excellent summary of the present state-of-the-art.

Gaines W. Monk
Manager
Mt. Vernon Research Co.

Sir:

Our registered trademark "HYDROX" was mentioned in the article on "Fuel Cells," on pages 21, 22, and 25 of the October issue of Industrial Research.

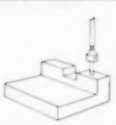
Unfortunately, the manner in which this trademark was used is improper as there was no indication that it is a trademark or that the trademark is the property of the Leesona Corp.

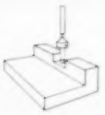
We regret the necessity of bothering you about this, but we cannot permit to continue any use of our trademark which might diminish its value. Therefore, we will be grateful if you will indicate that "HYDROX" is a registered trademark of the Leesona Corp.

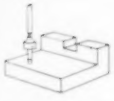
Anthony M. Moos
Vice-President & General Manager
Leesona Moos Laboratories Div.
Leesona Corp.

6

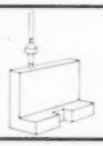
DIFFERENT MEASUREMENTS ON THIS PART IN LESS THAN A MINUTE!


PIECE HEIGHT


GROOVE HEIGHT


BOTTOM THICKNESS

BACK THICKNESS


WIDTH

LENGTH

BAUSCH & LOMB
SINCE B&L 1853

Made in America, to the world's highest standards.

Fast? You bet your life . . . but that's only part of the story. Bausch & Lomb DR-25B Optical Gage gives you *direct* measurement to 0.0001" over a 3" range on a bright, magnified scale . . . to 0.000025" if required. Designed for shop use, no other instrument of this type, at any price, achieves such precision.

Fast, easy, accurate . . . and only $875! Put the DR-25B to work in your shop and start savings of up to 85% in gaging time (job-proved by Aeroquip Corp., Taber Instrument Corp. and many others.)

Distributed in U.S.A. through the DoALL Company

BAUSCH & LOMB INCORPORATED
93024 Bausch Street, Rochester 2, N.Y.

☐ I'd like an on-the-job demonstration of the DR-25B with no obligation.

☐ Please send Catalog D-285.

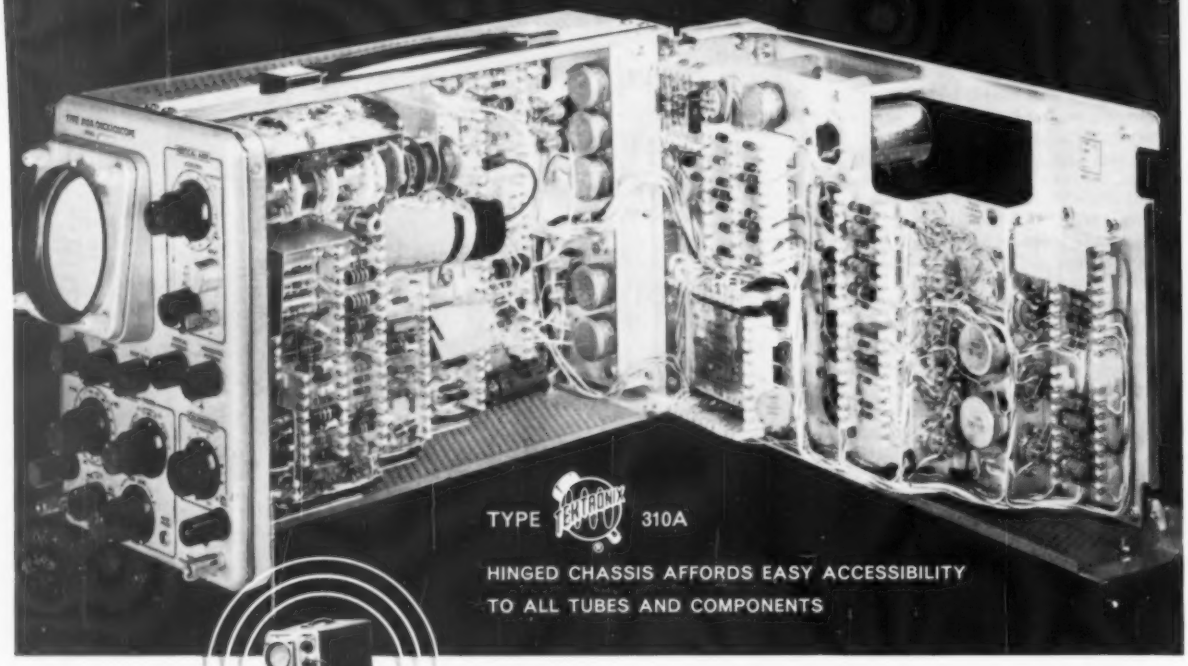
NAME ..... TITLE .....

COMPANY .....

ADDRESS .....

CITY ..... ZONE ..... STATE .....

...here's a little 'scope for BIG JOBS



Measuring deviations to quantity parts-per-million in similar units under test.

Instrumentation includes a Tektronix Type 310A Oscilloscope and the new *Electro Scientific Industries* precision-measurement console—which measures resistance, capacitance, and voltage ratio over wide ranges with direct traceability of accuracy to three reference standards certifiable by the National Bureau of Standards.

Photographed at Electro Scientific Industries, Portland, Oregon.

Need a precision-measurement tool in the dc-to-4 mc range?

A small-size, light-weight, semi-ruggedized instrument that operates almost anywhere from 50-to-800 cycles line frequency?

One that combines stability in performance, simplicity of operation, accessibility for maintenance?

Then consider a Tektronix Type 310A Oscilloscope.

For size, convenience, presentation of trace display—a Type 310A ideally suits precision-measurement applications at point-of-use . . . such as quality-control checks in production testing . . . or maintenance and calibration of complex electronic equipment in the laboratory or in the field.

Call your Tektronix Field Engineer for a demonstration.

TYPE 310A CHARACTERISTICS

Frequency Response—dc to 4 mc: 100 mv/div to 125 v/div; 2 cycles to 3.5 mc: 10 mv/div to 100 mv/div. *Risetime*—less than 90 nanoseconds. *Sweep Range*—0.5 μsec/div to 0.2 sec/div in 18 calibrated steps, continuously variable between steps and to 0.6 sec/div uncalibrated. *5X Magnifier*—extends calibrated sweep range to 0.1 μsec/div. *Triggering*—amplitude-level selection with manual or preset stability control, and automatic facility. *Horizontal Input. Amplitude Calibrator. Electronically-Regulated Power Supplies.*

Type 310A Oscilloscope **$625.00**
U.S. Sales Price f.o.b. Beaverton, Oregon

Dimensions—10" high, 6¼" wide, 17" deep. *Weight*—23½ pounds.

Tektronix, Inc. *P. O. BOX 500 · BEAVERTON, OREGON* / *Mitchell 4-0161 · TWX—BEAV 311 · Cable: TEKTRONIX*

TEKTRONIX FIELD OFFICES: Albuquerque, N. Mex. • Atlanta, Ga. • Baltimore (Towson) Md. • Boston (Lexington) Mass. • Buffalo, N.Y. • Chicago (Park Ridge) Ill. • Cleveland, Ohio • Dallas, Texas • Dayton, Ohio • Denver, Colo. • Detroit (Lathrup Village) Mich. • Endicott (Endwell) N.Y. • Greensboro, N.C. • Houston, Texas • Indianapolis, Ind. • Kansas City (Mission) Kan. • Los Angeles, Calif. Area (East Los Angeles, Encino • West Los Angeles) • Minneapolis, Minn. • Montreal, Quebec, Canada • New York City Area (Albertson, L.I., N.Y. • Stamford, Conn. • Union, N.J.) • Orlando, Fla. • Philadelphia, Pa. • Phoenix (Scottsdale) Ariz. • Portland, Oreg. • Poughkeepsie, N.Y. • San Diego, Calif. • San Francisco, Calif. Area (Lafayette, Palo Alto) • Seattle, Wash. • Syracuse, N.Y. • Toronto (Willowdale) Ont., Canada • Washington, D.C. (Annandale, Va.).

ENGINEERING REPRESENTATIVES: Kenyon Hawaii Ltd., Honolulu, Hawaii. Tektronix is represented in twenty-five overseas countries by qualified engineering organizations.

European and African countries, the countries of Lebanon and Turkey, please contact TEKTRONIX INTERNATIONAL A.G., Terrassenweg 1A, Zug, Switzerland, for the name of your local engineering representative. Other Overseas areas, please write or cable directly to Tektronix, Inc., International Marketing Department, P. O. Box 500, Beaverton, Oregon, U.S.A. Cable: TEKTRONIX

Some Ideas

for your file of practical information on graph papers

KEUFFEL & ESSER CO.

A graph can be defined as: "A picture of a collection of facts." Often, like that well known Chinese watercolor, a graph is worth a thousand words – or figures. There's no question that graphs speed up comprehension. In some cases, no other way exists to show the subtle interaction of statistics and data except by graph. It's no wonder that legions of engineers, architects, scientists and businessmen rely on graphs and charts to give them the complete information they need.

The big wonder is that more don't know and take full advantage of the fabulous variety of graph papers available from K&E. This is sort of a crusade with us – and has been ever since the turn of the century (a *billion plus* graph sheets ago).

Just The Right Sheet For You

The graph sheet shown below is just one of thousands of job-matched papers made by K&E. These are grids and patterns evolved to solve *specific* needs. The chances are roughly 1000 to 1 that we have exactly the paper you need to chart the statistics of your company or job.

Choosing That "Right Sheet"

What *is* the graph paper that will do the best job for you? (Actually, there may be more than one – dozens perhaps.) We could answer that here, but we've already done so in a brand new edition of our famed K&E Graph Sheet Catalog. Not only does this catalog guide you in the

selection of the sheets you need, it shows you – often full size, in color – the patterns in question.

We've printed an ample supply of this new catalog, and are prepared to send you your copy *free*. Just return the coupon below.

What Makes Graph Papers Different?

There's a wide gulf of quality in graph papers – more than you'd dream possible. Only the finest sheets can really accomplish the complex, accurate work they're designed for. That's why we build-in three important features:

PRINT. Every K&E Graph Sheet ever made was printed from precision-engraved plates by the *letter-press* process. Offset printing, to our way of thinking, relies unduly upon the vigilance and skill of the printer. Variation from lot to lot is a distinct possibility. We have never taken that chance . . . and we're the *only* manufacturer of graph papers that hasn't.

PAPER. All K&E graph sheets – translucent or opaque – are printed on papers with at least 50% rag content – in some cases 100%. Every square foot of this stock is examined in our quality control labs *before* being sent to the printer. Top grade paper means that adjustment upward in accuracy and long life which is so important to so many people.

PACKAGE. Locating graph sheets can be a chore if they're packaged in old-fashioned boxes or envelopes where you can't see what's inside. Especially true if you use a big variety of sheets. Solution: the new *visual* package offered by K&E. The package has a "window" in front so you can see the sheet inside. In addition, there's a full description of the style, number of grids, line color, type of paper, etc. printed on three sides of the package. Designed to serve as a file folder, the package can be stored flat if desired.

We'd like you to see this new package, and a representative sampling of K&E graph sheets you can more than likely put to immediate use. This too is yours free just for returning the coupon below.

And for all the facts about graph papers, and any other of the 9,000 products made by K&E, see your nearby K&E dealer.

12,300 variables at a glance. Here's a typical stock market chart used to study relative market action. Center line is market behavior of 540 stocks over 20-year period. Two basic stock groups of 25 and 50 individual stocks, averaged, are plotted against market (figured at zero per cent). Resultant chart shows all-important slope of curve which – far more than gross increases – tells the story of the stocks' vitality. No list of statistics, no matter how exhaustive, could give the relative interactions shown here. This picture is possible only with a graph.

But if we don't have what you want – if we lose that 1000 to 1 bet – we'll gladly pay off by working with you to create exactly what you need. We've done this thousands of times for other customers. Just recently it was the U.S. Bureau of Standards. We worked with them to devise two new sheets for recording the complex heat reaction patterns of various insulating materials. These two sheets are already "standards" in the electrical industry.

KEUFFEL & ESSER CO., Dept. IN-12 Hoboken, N. J.

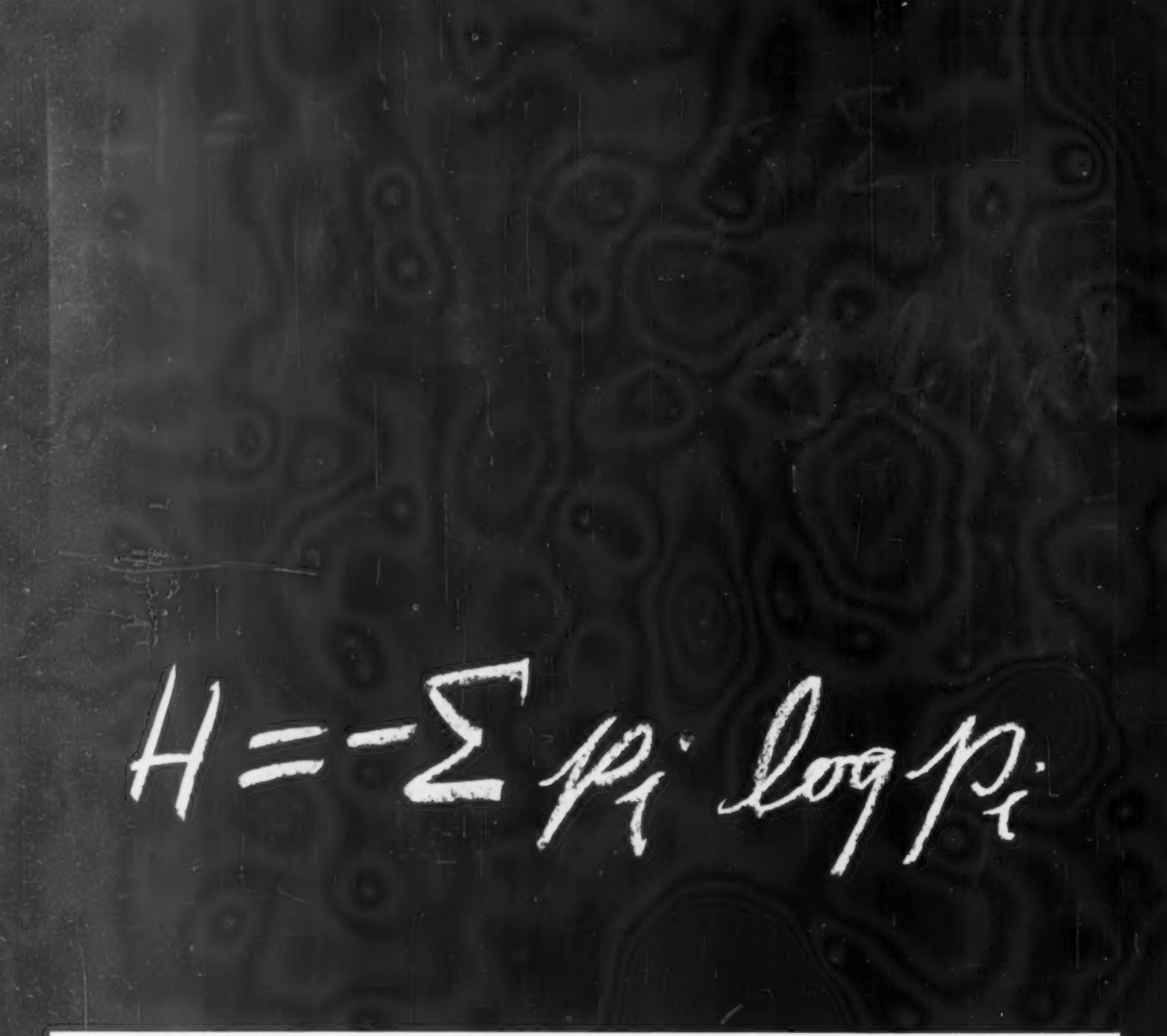
Please send me your new graph-sheet package with samples of K&E graph paper, and the latest K&E Graph Sheet Catalog & Selection Guide.

Name & Title: _____

Company: _____

Address: _____

2848



A basic formula from Information Theory . . . provides a measure of the amount of information in a particular type of message, such as TV . . . helps determine the frequency bandwidth, for example, required to transmit the messages. Information Theory, pioneered at Bell Laboratories, guides the search for better communications systems.

DISCOVERY AT BELL TELEPHONE LABORATORIES

New knowledge comes in many forms. Sometimes it comes in a mathematical formula. Usually it comes after much thought and experiment and the fruitful interaction of different minds and abilities. Most often, too, a particular discovery is small. But many small discoveries have a way of leading to big advances at Bell Laboratories—advances like the transistor . . . or, more recently, the gaseous optical maser, forerunner of communications at optical frequencies. Opportunities for discovery are enhanced by the abilities of the scientists and engineers and the range of the facilities at Bell Laboratories, *world center of communications research and development.*

MEMO TO: **Defense-oriented management**

FROM: **Industrial Research**

DATE: **December, 1961**

SUBJECT: **Action in the face of DOD cutbacks**

1. If the current cold-war crises subside, the nation's vast industrial research complex would be shaken adversely by a sharp cutback in defense spending. What are you doing to prepare for the possibility within your own company or research division?

2. Literally thousands of research possibilities are lying dormant because of concentration on pressing security and space needs. Much federal money now assigned to defense problems will be transferred to such areas as medicine, public health, mass transportation, housing, weather and climate, communications, and many other fruitful areas—if these projects are initiated by industry. The oceans, for instance, contain more things to be discovered than all of the dry-land projects undertaken to date.

3. Company-sponsored research programs are beginning to snowball. And they'll beget new programs. Typical of projects that only a few years ago would have seemed completely out-of-place are: new types of fabric dyes from Schenley Industries; conveyor control systems from Sheaffer Pen; human factors studies by ACF Industries; auditory transducer techniques by Bulova; hydrofoil craft by Grumman; and rocket fuels by the makers of Boraxo.

4. Such effort broadens the base of research and enables your company to build its in-house capability for government contracts or to work with other firms that have or are obtaining new R&D contracts.

5. Watch for a new problem: the marked tendency recently by the military—the Air Force in particular—to tighten up criteria for "admission" to specific bidders' lists. This move was necessitated, one high-placed Air Force official told Industrial Research, because of the sheer weight of staff work piling up as the result of invitations to bid. Agencies were receiving bids from 100 or more companies on a single project.

6. Clip the article beginning on the next page. Make sure your technical management, your "program development" men, your sales engineers read it. "How to Get Government R&D Contracts" and its companion piece in the November issue, "Can You Afford Government R&D Contracts?" may turn out to be the most important articles you've read all year.

HOW TO GET GOVERN

GOVERNMENT R&D CONTRACTS today are not necessarily the road to corporate profits. Some firms that have tried it and have come up with a mere 2% return on their investment feel they'd be better off to fire their huge R&D staffs and invest the money in stocks or bonds or even in commercial paper.

These shortcomings were discussed in last month's *Industrial Research* ("Can You Afford Government R&D Contracts?" page 13). Despite the facts that contracts can be cancelled on short notice, that profits are renegotiated, and that not all costs are allowed, many scientifically oriented firms insist that defense business itself can yield rather attractive earnings. Secondary advantages, such as improving corporate reputation, building a sound R&D division, and turning "swords into plowshares," are luring more and more companies into the Pentagon.

The government will look at anything

Almost without exception, the experience of such firms has been that government agencies—despite the welter of concepts and data submitted to them for evaluation—are never too busy to listen to new ideas or what your technical people consider better approaches to the problem of control, instrumentation, reliability, or almost anything else. Obtaining and successfully fulfilling R&D contracts today depends more on "team effort" than ever before. Our country's defense always has been a high enough stake

HIGH ALTITUDE *chambers are standard equipment in companies doing space research for the government. Wearing a pressure suit, a member of Republic Aviation's Space Environment Laboratory checks his ventilation lines during tests in the chamber.*

by **Dr. Theodore K. Steele,** *executive vice-president, Bulova Research & Development Laboratories*

MENT R&D CONTRACTS

to put buyer and seller on the same side in the matter of defense contracts. Therefore, such factors as capability, past performance, facilities, and know-how, rather than clever salesmanship, have in most cases determined who would build the nation's military hardware. Recent serious international implications, the concomitant accelerated pace of scientific discovery, and technological obsolescence give the "team concept" platitude a new genuineness.

The world of science and technology historically has been one of objectivity, the aim being discovery and development. Who makes the discovery and where it is made are of secondary importance. The true technical man's genuine enthusiasm at a "breakthrough"—even though the achievement was made by engineers of another company—is well known to technical management in government and industry.

This then is the environment of the world of research and development. A clear understanding of this climate is the first and basic requirement for any company trying to get government support for its R&D efforts. Such understanding has definite practical implications. It means, for instance, that the company engineer or scientist has become a vital communications link, a "salesman" in the company's transactions with government agencies. It means that the traditional company sales representative must understand more of his company's capabilities and the specific problems of his customers: his role is changed, as shall be discussed later in this article. But, the engineers or scientists, or the capability they represent, do the final "selling" for the company. Whether by personal contact or through written proposals, a meeting of minds between company engineers and those on the government agency staff is the forerunner to successful outcome of R&D contract efforts.

A good technical staff almost sells itself

The complexities of the defense R&D field today demand a high investment in engineering and scientific talent and facilities. No company unwilling to seek the best of both can hope to compete for long. Time is of the essence—and so is the government's R&D budget. Companies in the field are well aware that the ability of their technical people to make the right engineering decisions is vital. The most valuable resource of the R&D facility today is a technical staff not only oriented to the specific needs of the defense and space program right now, but one that can look ahead and anticipate the needs of tomorrow.

Advanced planning, recognition of sound and pertinent areas of R&D, and the willingness of company officers to give financial backing to those projects are vital considerations for obtaining government support later on. A company with the facilities and technical skills to initiate projects is in a better position than one that lets the government agency call all the shots. R&D competition is extremely keen these days and a company with a program well underway in a specific area naturally gets the jump on the competition if and when the government decides to enter the area.

All of this is very well, you may say. But contract officers in government are only human, and their knowledge of a company's capability comes, ultimately, from the company. Salesmen exist to sell, and all other things being equal, the company with the successful bid lands the contract. How big is the government pie, and how can you assure that

MECHANICAL HEART of a satellite timer, a tiny gear wheel developed by Bulova, has 300 precisely machined teeth on its circumference. Vibratory motions of an electronically impulsed tuning fork are transferred to the miniature gear by a ratchet-and-pawl mechanism. The gear then transfers the resulting rotary motion to a wheel train. In true "swords into plowshares" fashion, the gear is used as a special timer for long-duration military needs and for a consumer wristwatch called Accutron.

your company will have its rightful slice?

Four-fifths of the expenditures of the federal government for research and development—or an estimated $7.4-billion in 1962—are directed primarily to security needs. Department of Defense programs account for 66% of all federal R&D expenditures; the programs of the Atomic Energy Commission for 12%.

The federal pie . . .

Expenditures for non-defense programs are estimated at $2-billion in 1962 or 21% of total federal R&D funds. Of this amount, 48% is for programs of the National Aeronautics & Space Administration and 24% for Department of Health, Education & Welfare projects, chiefly the medical research activities conducted or supported by the Public Health Service.

The federal government supports more than 60% of the nation's entire research and development expenditure. Private industry finances about a third, and smaller amounts are provided from funds of foundations, educational institutions, and by state and local governments.

. . . Getting your slice

A grand total of money being spent this year by both the government and industry is estimated at more than $14-billion—almost $15-billion—arrived at by combining the DOD and National Science Foundation totals. This is three times what industry and government together spent in 1951.

Most important for the purposes of this discussion, of the total federal expenditures for R&D throughout the country, *slightly less than 70% are made through contracts with private industry*. Granted that we must have a technically sound R&D staff, the proper facilities, and a worthy project, how do you translate this capability into bankable contracts? Here are some questions you must ask yourself: (1) Is the project in an area where the company has a proven capability? (2) If so, is the project important enough to divert manpower from other company activities to handle it? (3) Does the company have at least a fair chance of getting the contract?

This final question is posed for a good reason. Obviously, if one or two other companies have invested time and effort in this particular area—and in so doing have won recognition in the field—

chances are one or both will get contracts.

One of the real problems facing the entire R&D industry has been the fantastically high cost of proposals. The complexities of today's defense systems, the fast changing requirements, and the amount of technical data that must be amassed to back up proposals can involve hundreds of thousands of man-hours. This means a tremendous expenditure of time that possibly could have been used more profitably in other areas or in company-sponsored projects.

It is true, however, that the technical staff may accumulate more knowledge in preparing a proposal —knowledge that can be useful the next time. Conversely, a "buckshot" approach in the business of bidding can be disastrous from an economic point of view. Furthermore, the capability and reliability of a company that bids on anything and everything that comes along are open to suspicion by government agencies.

Some rules-of-thumb for submitting proposals and bids certainly include these key suggestions:

- Completeness in preparation of bids is imperative; otherwise the bid and firm making it may be classified as "non-responsive." Even answers that seemingly have no bearing on the contract must be completed.
- Accurate information that can be backed up with financial statements, cost computations, drawings, and other material requested avoids time delays for confirmation. Often, a complete cost breakdown of each item is required. If you can pre-answer some questions the agency might logically ask later, so much the better.
- Firmness in quoting prices and delivery is important; the fewer "ifs" and contingencies the better.
- Promptness seems almost unnecessary to mention, except that if more time is deemed necessary to submit an adequate bid the contractor should ask permission from the agency as soon as possible so that the agency can extend its timetable and notify other bidders.
- Thoroughness in accuracy and completeness should be checked by someone within the company who is not directly involved in the preparation of the proposal or bid.
- Performance is the most important criterion. Many agencies use a "contractor's history file" that includes a place for checking past contracts as having been delivered or completed "on time" or "delinquent." There is no space for explaining a delinquency.

Mention was made earlier of the changing role of the company's sales representative. One good indication of this change has been the emergence of the sales engineer. Not chosen predominantly for smooth sales manners, but rather because of his technically oriented background and his talent for communication, he serves as liaison between the company's technical staff and the heads of the various divisions within the government agency.

An expert in ordnance fusing, warhead safety and arming systems, infrared devices, tactical weapons systems, and timers, Dr. T. K. Steele has participated in numerous government R&D programs. As executive vice-president of Bulova's R&D Labs, Steele manages the division's programs in electrochemical and electronic development and applied research. He holds a PhD in engineering science from New York University.

The sales engineer is an important team member for many reasons. He keeps his management and technical staff alerted to contracts that will be coming up for bids. And he spots trends in the agency's future requirements as a means of avoiding dead-end projects.

The sales representative must know the framework of each agency, who is in charge of what, the proposal procedures they follow, and other pertinent information concerning the agency's way of doing business. His most important overall function is to maintain an efficient relationship with the agencies — efficient from the company's as well as the agency's point of view. By giving his management and the technical staff the right information, he can save time and money which otherwise would be spent on wasted effort. He is a major factor in the making of right engineering decisions. Furthermore, since he is in regular contact with various government people he becomes the key factor in winning initial interest on the part of the agency in company-originated projects for which government funds may be available.

From the government point of view, the sales engineer can be a helpful industry contact, or he can be somewhat of a nuisance. For example, he should make every effort to see that company proposals and technical studies are concise and to the point, that meetings between company and agency personnel are meaningful, that any differences of opinion between company and agency scientists are ironed out as amicably and as rapidly as possible, and finally that company follow-through on a contract meets all the requirements asked by the agency. The company image is truly in his hands.

The brass path to contracts

In an attempt to elevate the company's image, many firms have adopted the method of taking on

a retiring military officer, installing him as an officer of the company, and letting him use his former contacts to promote business. The practice as just stated is dangerous and may produce an exact negative of what the company hopes to achieve. In fact, so much military brass has gone into industry recently that a Congressional committee has been set up to look into the matter.

Some companies wisely insist that their former colonels or retired generals *sell nothing*, but operate solely to organize the company's broad capabilities for a maximum contribution to defense production and, it follows, earnings.

For instance, Westinghouse hired Gen. Albert Boyd in 1957 after he ended a 30-year Air Force career. Boyd's last military assignment was as deputy commander of the Air Research & Development Command at Baltimore. Yet he brought with him no ready-made contracts. He did carry home his Air Force-developed formula of setting up a small central staff of specialists who knew the customers' situation intimately, who knew their company's capabilities, and who were technically competent to contribute ideas and solutions.

In six months the organization was in business as WASP—Westinghouse Advanced Systems Planning Group, a two-dozen-man general staff of scientists, engineers, management, and technical contact men who "do almost nothing but think." And the "thinking" consists of concepts practical not tomorrow or next year, but five or 10 years hence.

Similarly, Gen. Kenneth E. Fields, former head of the Atomic Energy Commission and later vice-president of ITT, joined Bulova some eight months ago to organize and solidify all of Bulova's non-consumer product activities. Since he joined the company, he has been busy building a corporate planning staff by tapping the resources and men of the other Bulova divisions.

Five years ago, Col. Charles L. Davis left Wright Field and joined Minneapolis-Honeywell's Aeronautical Div. in Minneapolis to head up a division planning team consisting of a handful of men. Today he heads the division and its 7,000 employes in plants across the nation.

Generals should be bridges, not salesmen

Unfortunately, these examples are not the rule throughout industry. Dozens of examples could be cited of retiring brass joining private firms as frontmen or supersalesmen.

Military requirements today are so bizarre, the technology so advanced, the standards so tight that few men can bridge the gap between the vast defense market and the manufacturing capacity that must supply it. Industrial organizations that use their retired generals to bridge that gap, instead of to sell, are in the lead. Their staffs become professional enough to evolve plausible weapons or other systems to do things never attempted before. At the same time they are commercially knowledgeable enough about their own organizations that they don't risk their companies' shirts on a project.

The following observations are from a central staff of the type described. While circumstances and problems of each company differ to a certain degree, these points might be helpful to your sales engineer as an overall summary of effective R&D liaison. You won't find all the answers here, but a few common sense rules of thumb are:

- Understand the job to be that of convincing the various contracting officers of the capability and reliability of your firm. You don't do this by trying to outwit him; neither do you do it with an excess of social amenities.
- Telephone in advance for an appointment. Guard your contacts' time as if it were your own.
- Maintain a policy of giving agency people what they want and when they want it.
- Try to bring something new to each meeting or conference with the agency. The agency people like to accumulate knowledge and information, too.
- Bring along one or more of your technical specialists whenever possible to meetings with the agency. Get them in contact with their counterparts at the agency level. This can save time for everybody.
- Follow-up even the briefest meetings within 24 hours with a written report to the agency—as well as to your own company.
- Encourage participation of your technical people in various scientific meetings and societies. Not only do they further their knowledge, but by making contributions in the form of technical papers and discussion, they enhance the company's reputation in the scientific community.
- Maintain a constant understanding of the agencies you're dealing with, their different divisions, their rules and procedures, their personnel, programs, and problems.

Reprints of this article are available by writing to Industrial Research Inc., Beverly Shores, Ind.
One reprint free—2 to 99 copies, 50c ea., 100 or more, 35c ea.

Keeping tabs on the government

The last point is the most difficult. The problem of industry keeping tabs on government parallels the government's problem of keeping tabs on industry. Government agencies and branches are in an almost constant state of flux.

For instance, the Air Force has reorganized its setup for managing weapons development, basic research, and general procurement, attempting to centralize direction of major programs and give closer attention to military space projects. Pentagon

officials say the changes will provide for tighter control of the more than $10-billion the service spends annually for procurement, research, and development.

All work on development and procurement of airplanes and missiles is in the process of being consolidated in a new command to be called the Air Force Systems Command. Previously some of this effort was directed by the Air Research & Development Command and some by the Air Materiel Command. Gen. B. A. Schriever, formerly ARDC commander, heads the new organization from Andrews Air Force Base near Washington.

Big missile programs formerly started out under ARDC. Then the Air Materiel Command took over as the missiles moved toward production. Even the Army Engineers got into the picture by being the authority for missile site construction.

Now all these activities, including Army participation, are directly under the new Air Force Systems Command. It directs all phases of major Air Force weapons programs, from drawing board to final test, before a weapon becomes ready for combat.

The changing face of warfare

The company wanting to sell its capability to the defense department also must realize the changing nature of modern warfare. System now replaces system without full-scale operation of either the old or the new. Tactical nuclear weapons, guided missiles, infantry squad radios, and many other projects are developed and produced without having been tried in even a mock combat.

Military maneuvers once were regarded as important means for revealing incompatabilities between sub-systems. Now they're too expensive. The cost of a single exercise employing an integrated system often is more than the development of such a system. Offsetting the reliance on maneuvers and tests is a trend toward greater emphasis on planning operations research, simulation, operational gaming, and other scientific techniques. Both government agency and contractor deal with equipment they may never see, much less test, in combat.

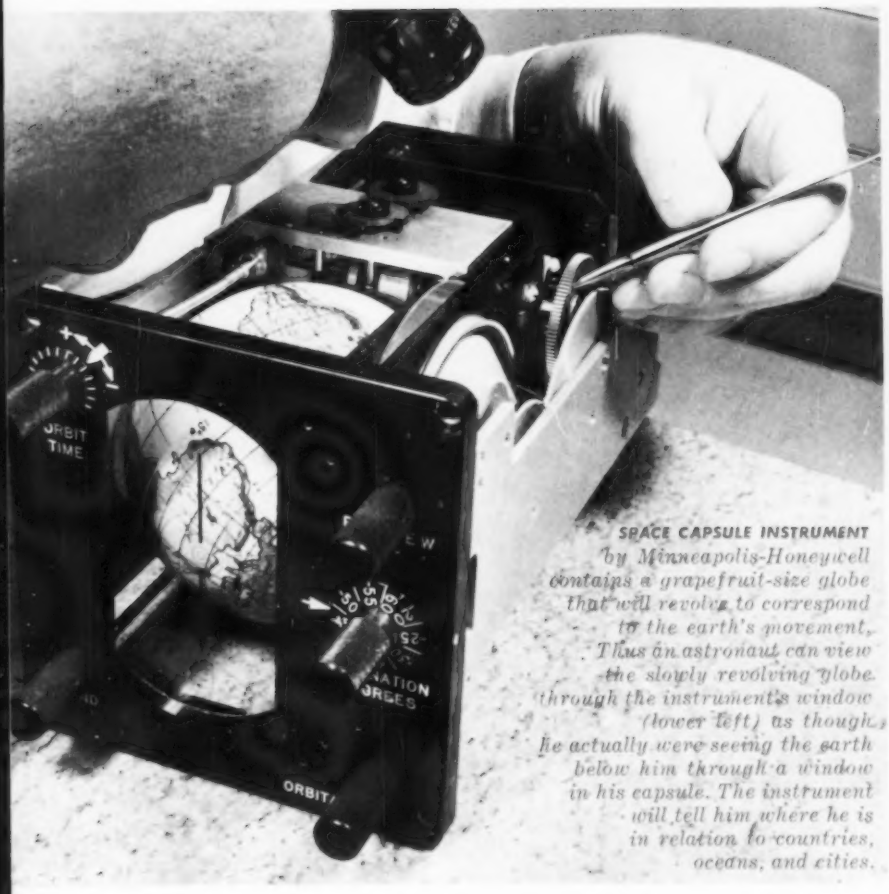
A detailed understanding of the government agency you are trying to sell; sound technological ideas, backed by company faith and dollars; and a common sense approach to selling your capabilities —this is the formula for success in getting government R&D contracts. ■

ELECTRONIC CYCLOPS *known as ESAR (electronically steerable array radar) can focus its "eye" simultaneously on space vehicles and aircraft at lower altitudes. The experimental model, comprised of 9,000 tiny radar antennas, has no moving parts as in conventional antennas. It was placed in operation recently by The Bendix Corp., built under contract with Rome Air Development Center and the Advanced Research Projects Agency.*

No hardheaded businessman, or Congressman, would have put up a dime in 1905 to help a bushy-haired, dreamy-eyed European physicist named Einstein pursue his theory of relativity. It is not the purpose of this article **by Luther H. Hodges, Secretary of Commerce,** to suggest that every piece of scientific research too complicated for government men to understand should be supported because it might yield an equivalent of nuclear power. Yet proposals for basic research should merit greater consideration from the government than they have received up to now. The question, then, is . . .

No stranger to government assignments before his nomination as Secretary of Commerce, Luther H. Hodges now is responsible for the scientific activity of the several Department of Commerce agencies. The largest part of this activity occurs within the National Bureau of Standards, the Coast and Geodetic Survey, and the Weather Bureau, and to some degree in the Patent Office, Office of Technical Services, Bureau of Public Roads, and Maritime Administration. Prior to serving as governor of the state of North Carolina for six years, Hodges enjoyed a highly successful career as an executive in the textile industry.

Should the Government Back More Basic Research?



SPACE CAPSULE INSTRUMENT
by Minneapolis-Honeywell contains a grapefruit-size globe that will revolve to correspond to the earth's movement. Thus an astronaut can view the slowly revolving globe through the instrument's window (lower left) as though he actually were seeing the earth below him through a window in his capsule. The instrument will tell him where he is in relation to countries, oceans, and cities.

GOVERNMENT AND INDUSTRY are overlooking an important opportunity to buy greater economic growth, stronger defenses, and better understanding, at bargain prices. The latest figures show that business and government combined spend less for basic research than American woman do in beauty parlors. Pure science endeavors simply do *not* occupy a proper place in our scale of values.

In terms of actual numbers, basic research budgets amount to only two-tenths of 1% of our $525-billion gross national product. Ninety-two per cent of all R&D funds go to applied research and development. There can be little question that the nation's basic research program must be strengthened. We cannot be lulled into thinking a $14-billion overall R&D expenditure is enough merely because it's a lot of money.

No one knows how much more basic research money American laboratories and scientists could put to good use. But even doubling the amount now spent would be an insignificant item on the national account books.

Basic investigations are just what the term implies — investments of time and money to explore un-

known or little understood areas. Such "seed" money often initiates a chain reaction, leading to countless applications of the new knowledge —often creating entire industries.

Research ←→ results

Such was the case with transistors, where a small program of basic inquiry into materials resulted in techniques of producing refined germanium and silicon. An entire industry was generated that has grown beyond all predictions. What's more, these successes have led to new inquiries into the basic nature of materials.

The same sequence has occurred in chemicals, agriculture, cartography, medicine, and other fields. Everywhere along the spectrum of scientific knowledge, new discoveries are changing the old time-honored ways of making things. This is an era when man expects more from science than he got from the ivory-towered thinkers of old. His needs range widely, from fallout protection to cheaper power, more products, and bigger profits.

SO MISSILE WON'T MISS, *an igniter for a solid-propellant missile engine is inspected after it has been put through rugged environmental tests at Bulova R&D Labs. The igniter, made for the Minuteman missile, incorporates new electro-mechanical design for greater reliability.*

Much of the new activity in research is under the auspices of the government. This sort of endeavor has a long history. In 1798, Eli Whitney was awarded a government contract to develop a system of manufacturing interchangeable parts for firearms. The new country sought a means of bolstering its still shaky independence and got a bonus in the form of mass production methods.

A long list of advances stemming from government sponsored research could be drawn. It would encompass such things as computers, printed circuits, anti-corrosion coatings, and freeze-dried foods. Such a list would show not only products developed for defense and later adopted by industry, but also methods, concepts, and basic standards.

The strides of yesterday's R&D can be dwarfed by those of tomorrow, but only if tomorrow's complex and often discouraging questions can be answered. Both government and industry must do some fundamental thinking about fundamental research.

300 firms do 90% of research

Consider industry first. With the far-ranging activities of government sponsored research, management must take care to avoid a critical pitfall in its thinking and planning. The government cannot and will not be able to support *all* the basic research needed by our economy. Ninety per cent of industry's research outlays are made by only 300 companies. Industry simply cannot adopt an attitude of "sure, we'll look into it for Uncle Sam." Industry scientists will have to look into many things for themselves. Research carried out wholly or partially by the government will have to expand, but industry sponsored basic research will have to grow too.

Department of Commerce bureaus primarily engaged in scientific activity constitute a large segment of the non-military research effort within the government. The National Bureau of Standards, Coast and Geodetic Survey, Weather Bureau, Patent Office, Office of Technical Services, Bureau of Public

Roads, and the Maritime Administration all are conducting major research programs. Nearly every executive department has at least some research effort underway.

Within the DOC, the work of the National Bureau of Standards is most basic to the largest number of commercial areas, and a fairly close look at its operations and problems is appropriate. The primary mission of NBS is to provide national leadership in the development and use of accurate and uniform standards and techniques of physical measurement. This leadership has proved profitable, and the work has been essential to assure interchangeability of parts, to permit effective application of research results to industry and commerce, and to provide basic quantitative data on which to build experimental programs.

'Seeding' commercial uses

Here are two examples of how NBS activities have acted as "seed efforts," resulting in widespread benefits to commerce:

- Basic NBS research in metallurgy, coupled with the bureau's pioneering efforts in the use of light waves to measure length, has paved the way for the development of ultra-stable gage blocks. The new gage blocks will enable industry to mass produce with great precision the vital electronic and mechanical components needed for the space age.
- For a more prosaic, but intensely practical example, railroads have been plagued for years by the problem of engine breakdown caused by wearing of metal parts. Recently, NBS chemists developed standard metallic samples which can be used for spectroscopic analysis of crankcase oil. Detection of metallic wear through the use of these high purity samples has application wherever engines are used.

Losing half the battle

There are serious problems in government basic research programs today. Nothing points up the really shocking shortcomings of our efforts better than a survey by the Aerospace Industries Assn., which revealed that the NBS standards and calibration service satisfied only 50% of the needs of its users.

Requirements placed on the standards and calibration program by the military and industry are growing at such a pace that even if efforts in the field of radio standards, for example, were doubled immediately, new demands would begin at once to outstrip the capability. In two years, the NBS standards and calibration program would be back in the same relative position as it is today—meeting only 50% of the requirements placed upon it.

There are other startling examples of the task at hand. Included in the new National Bureau of Standards laboratories will be a facility capable of measuring forces of up to a million pounds. It was needed two years ago, and won't be ready for another two years. By then, we *should* be able to measure accurately thrusts of 10-million pounds and more. The use of crude and inadequate methods for measuring rocket thrusts already has cost this nation hundreds of millions of dollars.

We can't measure plasmas

Another discouraging case is in the field of plasma physics. The behavior of extremely hot gases is so singular that many scientists consider plasma "the fourth state of matter." Yet, we simply do not have the basic scientific tools required to measure plasmas.

Neither awareness of these problems nor the ambition to solve them is lacking. New facilities and better funding are essential. The new NBS labs, now under construction near Gaithersburg, Md. will cost some $100-million. It is hoped that a realistic Congress will increase the money available to carry out the unglamorous and tedious basic inquiries on which new applied research can be built.

Technical management in government

But budgets and buildings alone will not allow NBS or any other government activity to meet tomorrow's research requirements. It is difficult to attract qualified, creative men to government service, and particularly so in the field of technical management.

Probably the least understood of all laboratory activities is the art of managing the incredibly complex research programs of today. The old walls separating disciplines have come down, but a pool of talent, if it is to produce meaningful results, still has to be an organized pool. Industry as well as government will have to replace the old, convenient academic pigeonholes with a newer, far more sophisticated manner of organizing and administering research.

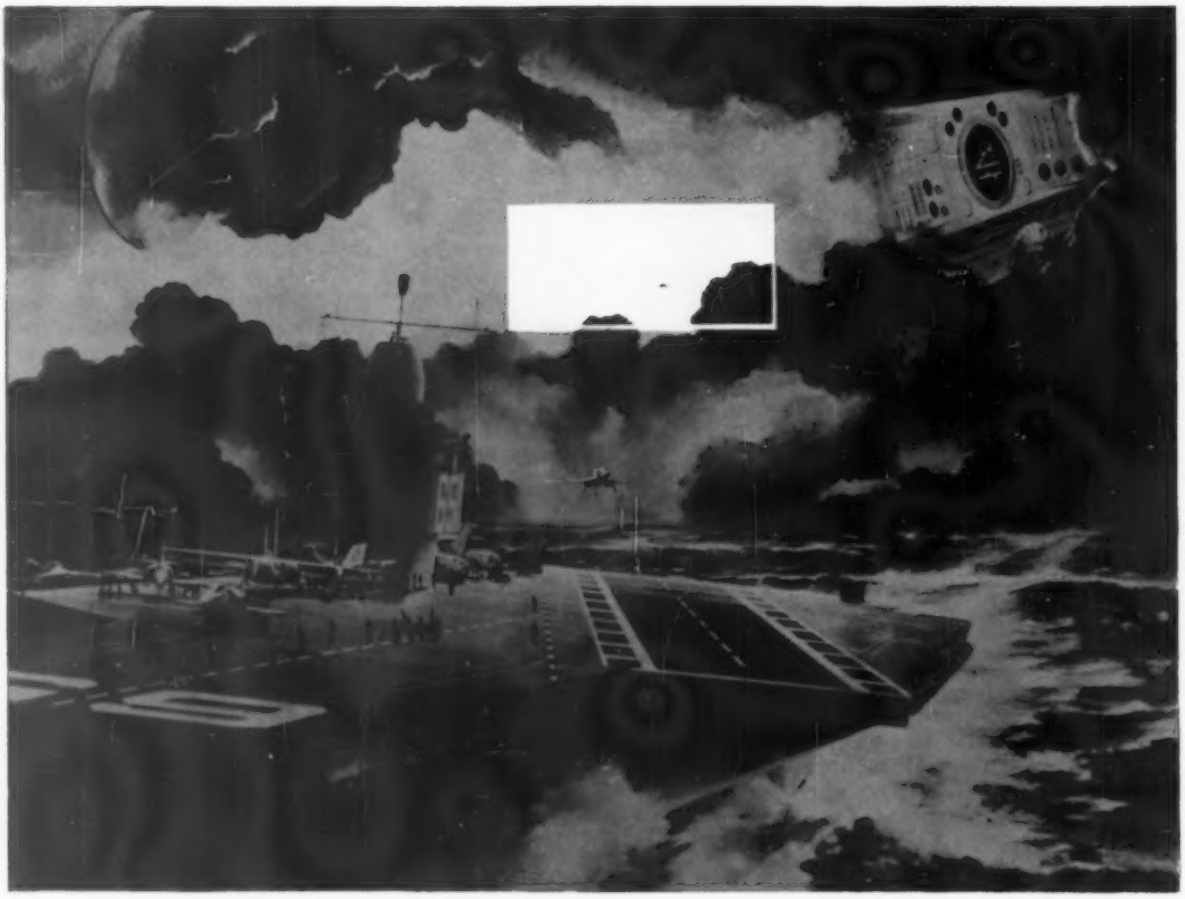
There is no question that the basic research demanded by a growing technology will get done, sooner or later. The pressures on basic inquiries generated by applied research are too strong to be ignored. The penalty for failing to do homework in basic research is a crash program costing many times more than basic knowledge needs to cost.

Government vs. industry

Some critics of government research efforts predict a clash with industry over expansion of government activities in this field. There is no reason for such a fight. The requirements for basic efforts are outrunning, and always will outrun, the combined ventures of government and industry. Secondly, much of the increased demand on government researchers comes from industry itself. Finally, the spectrum of science has reached a high level of sophistication. Answers to technology's complex problems are so difficult to find today that only the combined efforts of industry's and government's most creative minds can develop economical solutions.

One third of the products in common use today did not exist 10 years ago. Thoughtful business leaders realize that research is not merely desirable, but absolutely essential to competitive survival. Dr. Guy Suits, research director of General Electric Co., sums it up crisply: *"If you do not expect to be in business five years from now, there is no need for expenditures for scientific research."*

The Department of Commerce expects to be in business five years hence. Between now and then, we intend to strengthen the department's scientific organization in every possible way. The mandate of Congress establishing the Department of Commerce directs it to "foster, promote, and develop the nation's scientific and technical growth." It is a big order. We are going to need your help. ■



Bell research makes major contributions to aviation, missile and space programs

ALS—All-weather, automatic Aircraft Landing System illustrated. Electronic "window in the sky" automatically guides planes to safe landings in foul weather, at night, even in heavy seas. Purchased by Navy for installation on 10 modern aircraft carriers.

AGENA ROCKET ENGINE—Stop-and-start engine for the Discoverer, Midas and Ranger programs. It has functioned successfully on *all* of its more than 25 missions to date.

HIPERNAS—High Performance Navigation System. Designed for the U. S. Air Force, this self-compensating, pure inertial guidance system can pinpoint a long-range missile on target, or guide a satellite or space ship to any point in the universe.

STEERING GEAR FOR MERCURY ASTRONAUTS—Jet Reaction Controls, developed by Bell, control the roll, pitch and yaw of the Mercury capsule in space.

DOUBLE-WALL—Cools the heat of homecoming for space vehicles entering the atmosphere. Inner wall temperatures stay below 200° F, even though outside temperatures may soar above 2,000° F!

EETF—Electronic Environmental Test Facility at Ft. Huachuca, Arizona. Bell is operating the electronic phase of this program to analyze communications interference due to large volume of radio and electronic equipment being used in modern military operations.

BELL ROCKET BELT—First portable rocket device to give man free flight. Publicly demonstrated at Ft. Eustis, Va., June 8, 1961, it is now being studied by the Army for ship to shore landings and carrying the foot soldier over streams and rugged terrain.

BELL AEROSYSTEMS COMPANY • *Buffalo 5, N. Y.*
DIVISION OF BELL AEROSPACE CORPORATION

A textron COMPANY

THE RESEARCH TRENDLETTER

December, 1961

Dear Sir:

A system capable of handling the projected increase in air traffic with the fast reaction necessary for higher speed aircraft now beginning to appear has been proposed to the Federal Aviation Agency by Motorola Inc., Chicago Center, and General Precision Inc., Tarrytown, N.Y. The proposal follows hard on the heels of the FAA's recent announcement of plans to make its voluntary air traffic system for aircraft flying over 41,000 feet a mandatory safety measure by next March.

The proposed system, called ACCESS (for AirCraft Communications Electronic Signaling System) is a compatible digital system usable by all types of aircraft. It is essentially a technique for time-sharing the data messages with voice on existing voice communications channels. All that is required is the design of accessory equipment for use with existing radio tranceivers, and ground switching and message deciphering equipment for operation with the Air Traffic Control data processor. But development, acceptance, and installation of this equipment may require from three to five years.

aerospace

A six-place multi-purpose helicopter, described as "the smallest big helicopter flying," has been revealed by Hiller Aircraft Corp., Palo Alto, Calif. (Photo No. 1). The new "Ten99" craft has been in secret full-scale tests during the past six months. It was developed to satisfy requirements for a light fleet utility helicopter for the Navy, a Marine Corps assault support helicopter, and a modern, all-purpose civilian helicopter with both heavy duty and passenger adaptability. Its 500-hp Canadian Pratt & Whitney PT6 engine is the only turbine for light helicopters that has passed its official 50-hour U.S. government qualification tests.

A tri-service research program that may exceed $70-billion is expected to give the military a vertical take-off and landing aircraft capable of operating in any type of combat theater (Photo No. 2). The vertical craft will be developed and fabricated by the aerospace team of Ryan Aeronautical Co., San Diego; Ling-Temco-Vought, Dallas; and Hiller Aircraft. Projected as part of a system designed for rapid transport of combat troops, equipment, and supplies from assault ships or airfields into unprepared areas under all weather conditions, the vehicle will cruise at speeds of 250 to 300 knots, with a top speed of 400 knots at sea level. Four turboprop engines mounted on a tilting wing will power the craft.

The U.S. Air Force will be provided with what may be the world's first recoverable space booster system as a result of a new concept for air-launching the Blue Scout rocket into a deep space probe or into orbit from the X-15. The new method has been disclosed by the Aeronutronic Div., Ford Motor Co.,

Newport Beach, Calif., and North American Aviation Inc., Los Angeles. A Boeing B-52 eight-jet bomber would act as the first stage booster, the X-15 as the second stage, and the Blue Scout as the third and fourth stages (Photo No. 3). Both the B-52 and X-15 would return to earth after launch of the upper stage.

chemistry

The aging process of baby chicks and mice has been arrested and postponed for up to one year without ill effects by scientists at Monsanto Chemical Co., St. Louis. Growth was halted by changing the amino acid balance of diets. The National Institutes of Health has joined Monsanto in research toward possible use of growth suspension in therapy treatments for humans.

Seventy chemicals affecting reproduction among flies, and spelling their potential doom, have been discovered, according to U.S. Department of Agriculture investigators. Among these, the most promising appear to be the ethyleneimines which cause sterility in both males and females. Olin Mathieson Chemical Corp., New Brunswick, N.J., has developed an ethyleneimine, called Alpholate, which causes sterility in houseflies that eat it or walk over a surface treated with the chemical. The chemical is expected to be ready for commercial production by 1964. The next step that chemists must take is to establish that the sterilant does not affect man, beneficial insects, fish, or animals.

computers

The same electrical functions of a conventional computer 150 times its size and 48 times its weight are provided by a microminiature digital computer developed by Texas Instruments Inc., Dallas, for the Aeronautical Systems Div., U.S. Air Force. The advanced experimental unit, using semiconductor networks, is only 6.3 cubic inches in size and weighs only 10 ounces. (Photo No. 4). It uses 587 digital circuits, each formed within a minute bar of silicon material, as compared with the larger computer that uses 8,500 conventional components and has a volume of 1,000 cubic inches and a weight of 480 ounces.

Another miniature computer, weighing only 19 lbs, has been designed for space-vehicle and satellite flight guidance by General Precision Inc.'s Librascope Div., Glendale, Calif. The memory system, weighing slightly over 5 lbs and storing 112,000 bits, utilizes a thin film of helium as a bearing for the rotating drum, thus eliminating the mechanical wear of a metal suspension system and allowing closer tolerances between the drum and the magnetic devices that record and withdraw data. This feature, in turn, allows for a greater memory capacity.

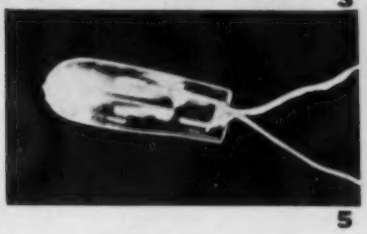
For the first time in the history of data communication, reception of stored computer-generated voice replies to questions can be accomplished with a new inquiry voice-reply device developed by the Remington Rand UNIVAC Div., Sperry Rand Corp., New York. The device enables transmission of inquiries to a Univac real-time computing system from a remote location and is expected to simplify and accelerate updating and reporting of changes in inventory, production, distribution, and sales in many businesses and industries.

1

2

3

4



5

Other computer developments include a new "Hypertape" system developed by International Business Machines Corp., White Plains, N.Y., that gets information into and out of computers faster than any commerically-available magnetic tape system. IBM also has developed two new devices for direct transmission of data by computers over leased telephone lines. Investigators at Lockheed Missiles & Space Co., Sunnyvale, Calif., are working on a new modular arithmetic for the Air Force under contracts calling for theoretical study and design of computer circuits. The new arithmetic, taken from a 2,000-year-old Chinese theorem, promises to make computer operations 20 times faster than possible at present.

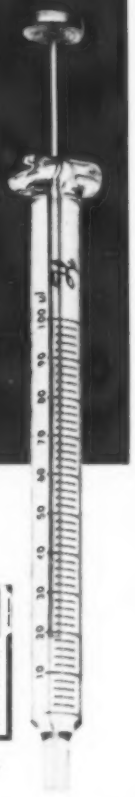
electronics

A Senate government operations subcommittee estimates that one-tenth of federally-supported electronic research and development may consist of "unwitting, needless duplication of effort." Sen. Hubert H. Humphrey (D., Minn.), subcommittee chairman, indicated the waste may add up to $200-million out of $2-billion currently expended for this type of work. He blames poor federal management of information on tens of thousands of current projects for the waste. The senator urges a national network of electronic information centers, coordinated with a larger network covering all scientific and technical information. He also is calling for a top policy mandate in the executive office of the president and within federal agencies for "effective and efficient information."

Subminiature lamps with exceedingly low current drain have been developed by Miniature Lamp Engineering Co., 350 Broadway, New York. The new lamps operate at 1.2 or 1.5 volts, drawing only 5 milliamperes. In spite of their tiny size, they give a light output of 40 to 50 millilumens and have a lifetime of more than 1,000 hours (Photo No. 5).

Hamilton Microliter Syringes

Precision Syringes from 1 ul to 500 ul



Here's the syringe that meets the demand of precision analysis by offering accuracy, greater sensitivity, speed and minute – yet accurate discharge. They're quality built, too, with individually fitted stainless steel plungers in precision bore NC glass to assure leak proof performance. By meeting critical demands, they have become the standard in gas chromatography, chemistry, biology and medicine.

FREE LITERATURE on Hamilton Microliter Syringes, just clip this ad to your letterhead and mail.

HAMILTON COMPANY, INC.
P. O. Box 307-P, Whittier, Calif.

INTELLECT GROWS ON A LOGIC TREE

MINIVAC makes possible a complete understanding of the exciting new world of computers. Logic trees make the programming of the most complex problem extremely simple. MINIVAC, a training digital computer, teaches the basic operations of even the largest commercial computers. Six comprehensive instruction manuals demonstrate to its operator how computers think, remember, calculate, make decisions and solve logical problems. MINIVAC is "the Christmas gift that makes sense" for hobbyists, businessmen, and students . . . anyone with an inquiring mind. **$85.00**

SCIENTIFIC DEVELOPMENT CORPORATION
372 MAIN STREET
WATERTOWN, MASS.

Scientific Development Corporation
Computer Sales Division
372 Main Street, Watertown, Mass.
Gentlemen:
Please send me ☐ MINIVAC 601 Check or money order enclosed. ☐ MINIVAC 601 C. O. D. ☐ complete literature on MINIVAC 601.
Name_____
Address_____
City_____ Zone____ State_____

THE I·R DICTIONARY

for technical management

EDITOR'S NOTE: *The I·R Dictionary is designed for use by technical management. Each column is concerned with technical terms used in the articles of that issue.*

axial flow compressor—a type of compressor used in turbojet engines to raise the pressure and increase the velocity of air flow. In the axial flow compressor the flow of air is parallel to the axis of the engine.

centrifugal flow compressor—a type of compressor used in turbojet engines. In this type compressor, the flow of air moves radially away from the center.

cryotron—a superconductive four-terminal device in which a magnetic field, produced by passing a current through two input terminals, controls the resistance between two output terminals. The cryotron was developed in 1956 by Dudley A. Buck and others at MIT. Buck suggested the name by which the device is now known.

gas turbine—an engine in which mechanical work is produced from the expansion of continuously flowing gas. In one design, for example, a jet of gas is discharged from a stationary nozzle against the blades of the turbine wheel, which transmits the impulse force of the jet into a torque to the shaft.

getter—a metallic substance placed into a vacuum tube and ignited to combine chemically with the residual gases, primarily oxygen, to produce a high permanent vacuum. The best getter materials are electropositive metals such as sodium, potassium, magnesium, calcium, strontium, and barium.

killed steel — steel that has been deoxidized by aluminum, ferro-silicon, or other ferro-alloys so that dissolved gases do not evolve during cooling in the mold.

turbofan engine—similar to a turbojet engine, except that a secondary air stream is bypassed around the turbine without going through the combustion chamber. The bypassed air is mixed with the discharge of the primary air stream from the turbine to effect increased thrust and reduce noise.

turbojet engine—an engine in which air, drawn from the front of the engine, is compressed by a turbine-driven compressor and heated by internal combustion of fuel. This produces a powerful jet of hot gases which turns the turbine and is discharged rearward to produce thrust.

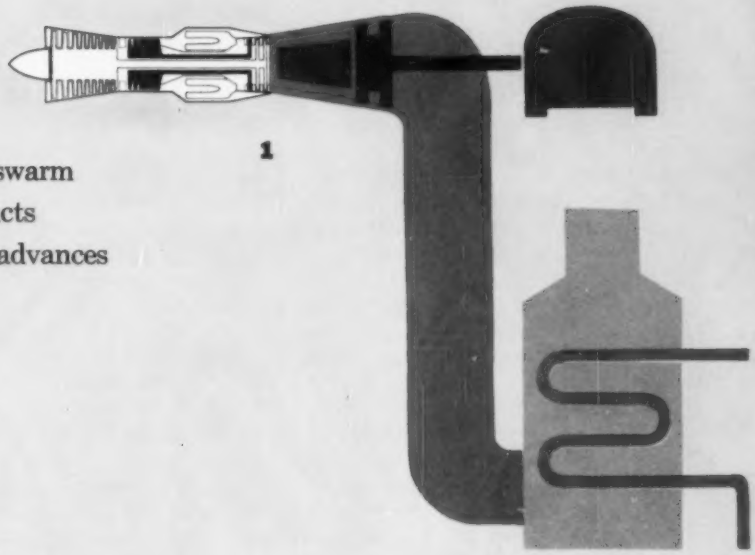
turboprop engine—similar to the turbojet engine, except that the turbine is used to drive a propeller as the main source of thrust.

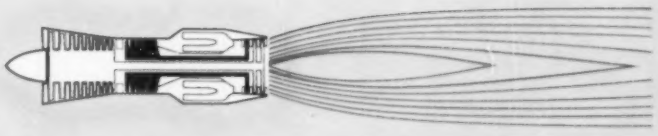
by **Dr. R. A. Budenholzer,** *director, American Power Conference*

Some cities use the hot exhaust of a turbojet to melt snow so that conventionally powered vehicles can swarm the streets to fill the air with the products of poor combustion. ▪ Engineering advances have widened turbine horizons. Turbo fans say it is clean, economical, efficient power; but after thirty-three years of development, it is still . . .

the controversial gas turbine

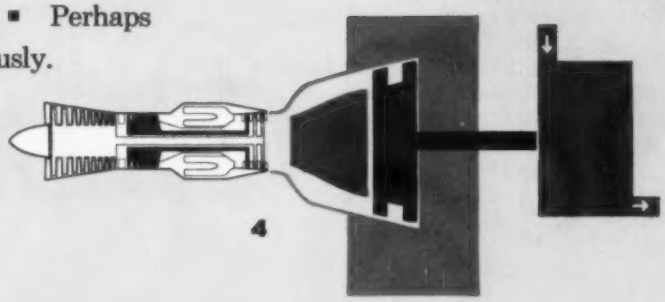
Painstaking research in gas turbines is opening new avenues for application of this controversial development, but practical limitations continue to present obstacles. The obstacles themselves provide the basis for the controversy. ▪ One of the major ones is whether high-speed precision-balanced rotors can be mass-produced at low enough cost to make gas turbines competitive with piston engines. Others are related to their ability to achieve better fuel consumption at part load and faster acceleration from idling. Until these obstacles are overcome, no one can predict the future of gas turbines accurately. ▪ Perhaps no engine has started off more auspiciously. The dramatic success of the gas turbine jet engine during World War II aroused the admiration of engineers all over the world and





Turbines turn in lower cost in a variety of uses: supplying heat and power for processing (1), thrust for propulsion (2), and shaftpower to drive generators (3), pumps and compressors (4).

Schematic concepts courtesy of Pratt & Whitney, Div. United Aircraft Corp.



stimulated their interest in adapting it to peacetime uses.

Immediately after the war, all kinds of new applications were investigated and optimistic predictions concerning its future were made, many of them premature and exaggerated. As soon as the engineering difficulties and practical realities of gas turbines became apparent, a period of skepticism followed. This skepticism now is giving way to optimism in the wake of current research and development.

Gas turbine aircraft engines already have replaced piston engines to a great extent. In electric power generation, gas turbines are used as auxiliary units for carrying peak loads, and various combinations of gas and steam turbines are being used to improve the efficiency of steam plants. Many proponents also are confident that gas turbines will replace reciprocating engines in automobiles.

Enter the turbofan

In military jet aircraft, for example, gas turbines virtually have replaced the reciprocating engine. The jet also is edging out propeller driven aircraft in commercial air transportation, especially for long, high-speed transcontinental runs and transoceanic flights.

Now the "turbofan" engine, a new development, is expected to reduce the chief disadvantage of jet engines for commercial transportation—the need for exceptionally long runways and low fuel economy during take-off. The turbofan is similar to conventional jet engines, but obtains increased take-off thrust by passing the air around the engine and discharging it at the rear without going through the combustion chambers or turbine.

The effect of the increased volume of air accelerated toward the rear of the engine is somewhat similar to turboprop engines, which obtain their thrust from two sources, propeller and jet exhaust. However, the ratio of thrust obtained from bypassed air and regular engine exhaust with turbofans is not as great as that with turboprops.

American Airlines currently is converting its entire jet fleet to the new turbofan engine. The change will increase take-off thrust about 25% and cruising thrust about 20%, according to airlines officials. If the plane is flown at the same speed as before conversion, a 20% saving in fuel consumption will be realized. But, if flown at maximum cruising speed, the plane will exceed its speed by 40 mph and still realize a 5½% saving in fuel consumption. In addition, the increased take-off thrust makes it possible to reduce runway length by 1,000 to 1,750 feet, and eliminates the need for carrying about 4,000 lbs of water on the plane for injection during take-off.

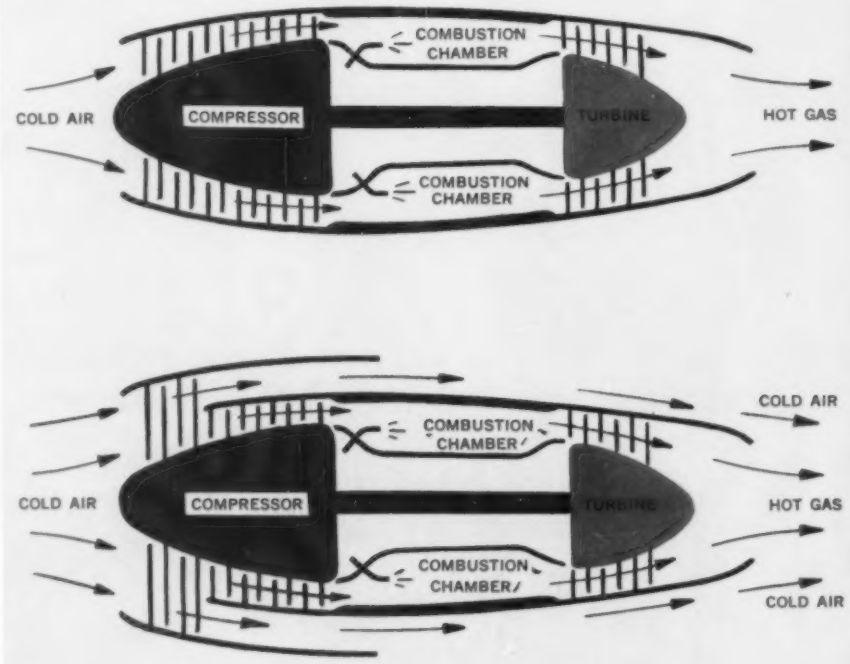
Both Pratt & Whitney Aircraft Div., United Aircraft Corp., East Hartford, Conn., and General Electric Co., Schenectady, N.Y., manufacture fan-type engines. Pratt & Whitney places the fan in front by extending the compressor blading, while GE places it in the back where it is powered by a low-pressure turbine. In either case, the basic principle is the same.

Midget jets for light planes

Among frontiers still existing in the aircraft field are the development of jet engines for powering such varied aircraft as helicopters, vertical take-off and landing craft, supersonic trainers, drones, missiles, and light planes.

A new midget-sized turbojet engine for possible use in the light airplane industry was developed recently by Williams Research Corp., Walled Lake, Mich. The engine employs a compression ratio of four to one and operates at a speed of 50,000 rpm. It weighs only 20 lbs and develops a thrust of 70 lbs, approaching the thrust to weight ratio of large jet engines in modern military and commercial aircraft.

The engine could bring jet power to the small plane field, according to the developers. It is so small,



light, and inexpensive that several could be submerged in a single wing contour. Much remains to be done in tailoring a plane to this type of engine because of high take-off and landing speeds. These speeds would have to be reduced to satisfy the major market for light aircraft.

Williams Research believes the tiny engine has possible application in helicopters. One engine could be mounted on the tip of each rotor blade to provide sufficient thrust to operate a four-place helicopter.

A tiny, 23-lb turbojet engine that will build up 85 lbs of thrust also was unveiled recently by Williams. Designed for light aircraft, the engine can be used for non-aircraft applications, such as automobiles, trucks, and boats, when redesigned with a shaft and reduction gearing.

Continental Motors Corp., Toledo, O., has announced development of a 210-lb, 500-hp engine

1

2

3

MIDGET-SIZED TURBOJET ENGINE *weighing only 20 lbs (1) could bring jet power to the light airplane field. Developed by Williams Research Corp., Walled Lake, Mich., the engine can build up a thrust of 70 lbs. A gas turbine that can serve as a long-life burning power source for air conditioning or power generation (2) is being developed by Solar Aircraft Co., San Diego. A major breakthrough has been reported by Chrysler Corp.'s Engineering Div. with the development of a gas turbine automobile engine (3) that can achieve the rapid acceleration and engine braking characteristics long sought in the turbine engine field.*

A SIMPLE MACHINE AND ITS OBSTACLES

The basic principle upon which the gas turbine operates is illustrated in diagram 1. Air is drawn into a compressor, either the axial type similar to those in aircraft jet engines (2), or the centrifugal type similar to those in small gas turbine engines.

Intake air is compressed to several times normal atmospheric pressure and delivered to a combustion chamber where the gases are heated to a high temperature before admission to the turbine. As the heated gases expand through the turbine, they exert pressure on the blade. The pressure turns the shaft with sufficient force to drive the compressor and the load.

Advantages of the gas turbine engine include its compact form, ability to operate on almost any liquid or gaseous fuel, superior torque characteristics, fewer and less complicated parts, and no need for a warmup period.

Two major obstacles to turbine efficiency remain, however; gases are exhausted by the turbine at too high a temperature, resulting in a waste of heat added by the fuel, and turbine efficiency is decreased at part load when the temperature of gas leaving the combustion chamber is reduced to lower the power output.

Providing a regenerator to absorb excess heat thrown away in the exhaust and dividing the turbine into high- and low-pressure sections, each on separate shafts can overcome the two obstacles partially. Less air flows through the compressor and turbine for a given power output and a higher temperature level in the combustion chamber, thus resulting in improved part load thermal efficiency.

Another improvement is intercooling during compression to lower the average specific volume of air during the latter stages of compression. The amount of work required to drive the compressor is reduced and the amount remaining to power the load is increased. The method is effective only when regeneration is used, because air leaving the compressor after intercooling is lower in temperature. Without regeneration, more fuel would be required to heat the air to the desired inlet temperature.

that will be produced by the company's subsidiary, Continental Aviation and Engineering Corp. The engine can be mounted either as a turboshaft engine for helicopters or, combined with a propeller, as a turboprop for twin-engine aircraft.

Numerous applications for all types of small gas turbine engines also exist in the so-called "auxiliary power unit" field. Here, turbines are used for generating vehicle guidance and control power on missiles, pressurizing and air-conditioning cabins, starting of engines, and many other purposes.

A turbine in your auto

Greatest area of interest and speculation concerning the future of gas turbines revolves around whether or not they eventually will replace reciprocating engines in the passenger automobile field. Strong proponents can be found for either side, but one thing is certain: all three of the major automobile companies, Chrysler, Ford, and General Motors, are pushing to produce an automobile gas turbine engine that will be fully competitive with present-day reciprocating engines.

Reason for these extensive research programs is not hard to find. First, present advantages of reciprocating engines over gas turbine engines appear to be limited to: lower manufacturing cost, lower fuel consumption at all loads, and faster acceleration from idling.

In contrast, advantages of gas turbines over reciprocating engines include: smooth, vibrationless, nonreciprocating power; simple construction with fewer moving parts; and superior torque characteristics that may make it possible to eliminate or simplify the automatic transmission. Also, the gas turbine engine is much smaller and lighter than a reciprocating engine of corresponding power and performance. It can run on a multitude of liquid or gaseous fuels and would not require high octane fuel.

Lack of a multiplicity of complicated moving parts in gas turbines reduces the lubrication problem and should increase the life of the turbine far beyond that of present-day reciprocating engines. Oil consumption is almost negligible. Because the engine is almost as easily started at low temperature as at room temperature, no difficulty should be experienced in starting the engine at −40 F. Other plus factors are that neither a cooling system nor a warmup period are required.

In the face of these advantages, it seems almost a miracle that the gas turbine already has not superceded the reciprocating engine. The chief reason why it has not lies in the advantages cited for the reciprocating engine. These advantages are extremely important to the average motorist. The first two directly affect his pocketbook, and unless a gas turbine that can compete with the reciprocating engine on an economic basis is built, there is little hope for its future. The third is an important performance feature: no one wants a car that is sluggish at the stoplight.

A leading figure in the power field, Dr. R. A. Budenholzer is a significant contributor to the advancement of gas turbine technology. He became director of the Midwest Power Conference in 1949, and organized its successor, the American Power Conference in 1952. He is professor of mechanical engineering at Illinois Institute of Technology and serves as senior scientist and consultant to Armour Research Foundation.

If the gas turbine is to power the automobile of the future, the three advantages of the piston engine obviously must be overcome.

Cost down—efficiency up

Much of the research and development work of the last decade has been devoted to the development of compact, lightweight, high-efficiency, low-cost heat exchangers as regenerators in small gas turbines. Indeed, the key to whether or not the gas turbine ever will replace the reciprocating engine in the automotive field hinges largely on the sucess of this endeavor. Williams Research and the major automobile manufacturers are working on heat exchangers.

Recent progress in the precision casting of special alloy turbine wheels also has been encouraging. Many engineers, including Chrysler's executive engineer, George J. Huebner Jr., believes that mass production techniques will cut tooling costs to half the cost of a new reciprocating engine and thus eliminate cost differential as a factor. If this is true, the only obstacle, as far as manufacturing cost is concerned, is the manufacturer's willingness to assume the risk of mass-producing the turbine.

A long time will be required to sell such a major undertaking. For one thing, the public first would have to be sold on the idea of a gas turbine automobile to assure sufficient sales for complete success of the venture. Many other engineering, psychological, and business problems also would be involved.

A solution for fuel consumption

As far as fuel consumption is concerned the problem now appears to be well on its way toward solution. A major breakthrough in the successful development of lightweight, long-life, highly efficient rotary type regenerators for recovering excess heat from the exhaust gases seems near at hand. Both Chrysler and General Motors have built successful turbines using rotary regenerators and Ford has been working on compact, efficient stationary regenerators. An adequate, long-life seal against leakage losses is the only unresolved problem in the development of rotary types.

One drawback of the gas turbine engine is the relatively high increase in specific fuel consumption with decrease in load. Since the ordinary passenger automobile runs at only a small fraction of its rated capacity most of the time, increased fuel consumption is a serious problem. Use of a two-shaft turbine arrangement will improve the specific fuel consumption at part load. However, it leaves a great deal to be desired.

One solution that offers promise is the use of variable area nozzles

for the second-stage turbine.

With this device, the nozzle area can be decreased at part load to run the compressor at a slower speed than at full load. Less air flows through the turbine to sustain a turbine inlet temperature near the maximum value, and thus take advantage of the higher thermal efficiency obtainable with high turbine inlet temperature. The result: specific fuel consumption at part load almost equal to that at full load.

IDEAS AND APPLICATIONS #7

Gas Turbines for Industry

A lighter-weight version of the gas turbine engine that will be used to power the U.S. Maritime Administration's 80-ton hydrofoil craft, the H. S. Denison, has been developed for industrial and marine use.

The multiple fuel, 500-hp turboshaft engine, coupled with a direct current generator on a portable skid, has been put into operation by an Oklahoma oil well drilling firm to supply electrical power for drilling rig components.

Developed by General Electric Co., Schenectady, N. Y., the 1,000-lb engine is a simple cycle, two-shaft gas turbine capable of operating on various liquid fuels or natural gas. Although it is not as lightweight as aircraft-type gas turbines, it has a favorable weight-to-power ratio making it suitable for applications where mobility or space are factors.

Other promising applications include a variety of standby and continuous duty generator sets, and pipeline or other pump and compressor drives. Also being studied are applications in which the engine's exhaust heat can be recovered to produce steam for chemical processes, or heating or cooling requirements. Large vehicle, ground effect machine, and marine propulsion uses also are being considered for the engine which weighs less than one-tenth as much as piston engines of similar power rating.

Major components are a gas generator, consisting of a compressor, combustor, and turbine, and an aft-mounted power turbine that harnesses the energy in the exhaust from the gas generator section, converting it into mechanical horsepower.

The compressor consists of three axial stages and one centrifugal stage, driven by a single-stage turbine. The power turbine, also single-stage, transmits power to the output shaft through two steps of gear reduction. It may be operated at either a fixed (isochronous) power turbine speed, or over variable speed ranges depending upon application requirements. ■

INDUSTRIAL RESEARCH, BEVERLY SHORES, IND.

Full throttle acceleration

Low acceleration from idling also can be alleviated by proper application of the variable nozzle principle. When accelerating, for example, if the nozzle is opened more than during normal operation, the pressure drop across the first turbine stage that drives the compressor will be increased, and more power will be delivered to the compressor. The compressor thus accelerates to full speed more rapidly than otherwise and full throttle can be applied for acceleration without fear of stall.

A bonus advantage of the variable area nozzle is its potential application as an automatic braking mechanism for downhill operation that is similar to an automatic transmission in conventional autos.

Agreement is almost unanimous that the gas turbine will find wide application in all types of trucks, tanks, earth moving equipment, and other heavy duty applications where the engine is operated under high load conditions much of the time. Its chief advantages here are similar to those for automobiles.

Another successful application of gas turbines has been in the railroad industry. However, the diesel engine is so well established as a highly efficient, versatile, and economical power plant that it will take years to supplant it with a gas turbine.

Because of space limitations in railroad applications, it is difficult to build a gas turbine unit with an efficient regenerator. Until this handicap can be overcome, gas turbines cannot hope to approach the fuel economies offered by diesels. The chief advantage of gas turbine locomotives is low maintenance.

Turbine powered boats: big and little

Gas turbines also show promise for powering medium-size ships. Up to now, however, too few units have been built to justify any concrete predictions. One mass market that could become second only to the aircraft and automobile market is the outboard motor.

Williams Research Corp. has invested more than $1-million in research to develop a small, lightweight, low-cost gas turbine competitive with medium-priced recip-

rocating engines for outboard motor applications. When the unit was tested in a small speedboat, it demonstrated performance and economy characteristics approaching those of the best modern piston engines, and it ran more quietly and smoothly. The engine runs at approximately 60,000 rpm, driving the propeller at about 5,000 rpm.

Another new and exotic marine application is the gas turbine powered hydrofoil recently proposed by the Navy. The patrol craft will be powered by two 3,000 hp gas turbine engines plus a 600 hp diesel. At high speed the craft rises out of the water and is supported on foils extending into the water. A somewhat similar application is the hydroskimmer, a device supported above water by a cushion of low pressure air similar to air supported ground vehicles. (See I·R, Vol. 3, No. 3, "Aircars and the 'Terresphere.'")

The extent of marine applications for gas turbines is demonstrated by the U.S. Navy's purchase of 397 gas turbines varying in capacity from 46 to 4,000 hp by the end of 1959. Most of the units were supplied by The Boeing Co. and Solar Aircraft Co.

Gas turbines provide auxiliary power for utilities

A totally different application of gas turbines is in the electric utility industry. Although gas turbines are not expected to compete successfuly with large central station steam turbines now generating over 80% of the nation's electric power, they are finding an important place in the utility field.

Carrying peak loads economically is a major problem in the electric utility industry. The cost of providing increased generating capacity for relatively short periods of time adds a disproportionately heavy burden on the operating cost of the system. The investment required for larger steam turbine generating equipment often may prove to be more expensive over the long run than the addition of a few gas turbine generators at strategic locations.

Gas turbines are particularly attractive as auxiliary units because they can be built at a lower installation cost than equivalent steam generators. They also can be packaged suitably for outdoor use and moved easily from one location to another as the system grows and power requirements change.

Fully automatic, the units can be operated by remote control for economical overall system operation. No cooling water is required and the units operate on liquid or gaseous fuels that are most economical for a given location. They are available in sizes ranging from about

IDEAS AND APPLICATIONS #8

Keeping Track of Patents

Keeping track of who owns what patent, where it is valid, and when it will expire is a major job for most engineering and electronics firms.

The once burdensome job of patent record-keeping now is being handled through automatic data processing machines at Dorr-Oliver Co. headquarters, Stamford, Conn. In the Dorr-Oliver patent system, the first of its kind in industry, all patent information is punched into some 9,000 IBM cards.

The result: by feeding cards into data processing equipment, thousands of records can be sifted in minutes to locate specific information. Thus the parent company and 15 subsidiary organizations can be kept completely informed on the status of active patents through machine-produced reports.

Many firms must keep track of what is under patent protection, in what nations this protection is valid, when it expires, when various taxes are due, the owner of the patent, code numbers (application number, patent number, case number, etc.) associated with the patent, and other important information.

With the data processing system, triple the previous volume of patents can be handled daily. More information can be recorded and more reports produced by one clerk working just one hour each day.

Dorr-Oliver, for example, regularly runs 10 different reports that feature the same information broken down by different categories. One report lists patents by countries and class. Another lists patents by number. Still another produces an expiration date order, and another, tax-due dates. Thus a tax date cannot slip by and jeopardize the effectiveness of a patent because no one knew it was due. ■

5,000 to 27,500 kw, and the units can be supplied in pairs or in any desired multiple. Large peaking reserve capacity thus becomes entirely feasible with gas turbines. Both Westinghouse and GE manufacture gas turbines for utility applications.

Gas turbine—steam turbine schemes

Conventional steam plants rapidly are reaching a point where it is extremely difficult to achieve an increase in efficiency, because the pressure and temperatures already employed are near the economic limit and the added expense of going any higher usually is not justified. By using a gas turbine in conjunction with a conventional steam turbine plant, plant efficiency can be raised from 3 to 8%, depending on the cycle arrangement and steam conditions.

For example, a special pressurized-furnace boiler, designed to generate steam in the conventional manner and at the same time serve as the combustion chamber for a gas turbine, can be used. Air is compressed to about 70 psig (pounds per square inch gage pressure) in a gas turbine driven compressor and then directed into the pressurized furnace of the steam boiler, where it combines with either gaseous or liquid fuel and delivers a large part of its heat to the steam generated in the boiler. The steam is used in a conventional turbine to produce power, and the gases leaving the boiler are directed through the gas turbine to generate additional power.

Studies by General Electric indicate a 7% savings is possible for a plant operating with steam at 1,450 psig and 1000 F when an oil-fired gas turbine operating at 1450 F is used. The steam turbine delivers 40, 160 kw and the gas turbine 5,700 kw. One disadvantage, however, is the need for a special pressurized furnace boiler.

In another scheme, a simple-cycle gas turbine is combined with the steam cycle to direct hot, low-pressure gases exhausted from the turbine into the boiler furnace, where they give up their heat to the steam being generated.

A study of a huge 678,500 kw plant operating on a similar cycle was recently completed by Westinghouse. The plant employed steam at 2,400 psi and 1000 F, with one reheat at 1000 F. The study showed that a 3.3% heat rate saving could be realized at full load, with comparable savings at part load. To produce the same saving, steam temperature would have to be raised to 1100 F after reheat. A comparable increase in efficiency would require the pressure to be raised to 3,500 psig, a very expensive proposition.

Taking into account all construction, investment, and operating costs of both the combination gas turbine-steam turbine plant and the corresponding conventional plant, it was estimated that electricity could be generated for 5.977 mils per kw hr in the combination plant, compared with 6.095 for the conventional plant. This is a saving of almost 2%. With such savings possible, the combined cycle offers a promising future for large gas turbine units.

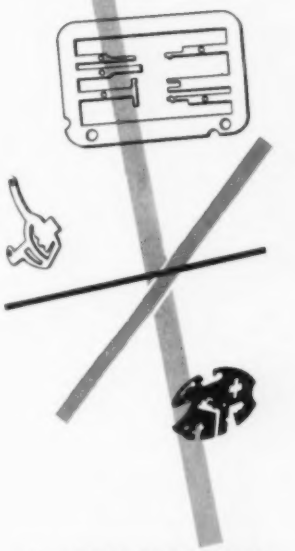
A booster for nuclear power

A third area of promise is in connection with gas-cooled nuclear reactors. Westinghouse currently is building gas turbines for a high temperature gas-cooled reactor plant being developed by General Dynamics Corp. for the Atomic Energy Commission and Maritime Administration.

The unit is a compact, high performance system directly coupling a high temperature gas-cooled reactor with a closed-cycle gas turbine. It operates at peak efficiency at power settings ranging from 10% to full load.

With the exception of aircraft, more turbines have been built for industrial applications than for any other use. Many are used in the oil and gas industries, and are ideally suited for gas pipeline pumping service. In a recent survey, 592 units, exclusive of aircraft and having capacities of 1,800 hp or greater, were reported by 24 companies throughout the world. Grand total capacity of all units amounted to 5,671,180 hp. This is an impressive figure, one that firmly establishes the gas turbine as a major industrial prime mover and dispels the skepticism of the development's severest critics. ■

thin metal parts



THE MOWBRAY COMPANY — specialists for 20 years in the precision fabrication and etching of metals — now offers THIN METAL PARTS produced to your specifications, **quickly and economically.**

Precision etching techniques and strictest controls allow us to fabricate all common metals into the most complex shapes — any hardness, any thickness to .015.

Contact us about **your** particular problem — any quantity, from a prototype to a million.

FEATURES

- **LOW COST** . . . no tooling expense
- **RAPID SERVICE** . . . no tool-making delay
- **UNIFORMITY** . . . no tool life factor

We can produce parts impossible to fabricate by any other method.

Write or call collect for further information and quotations.

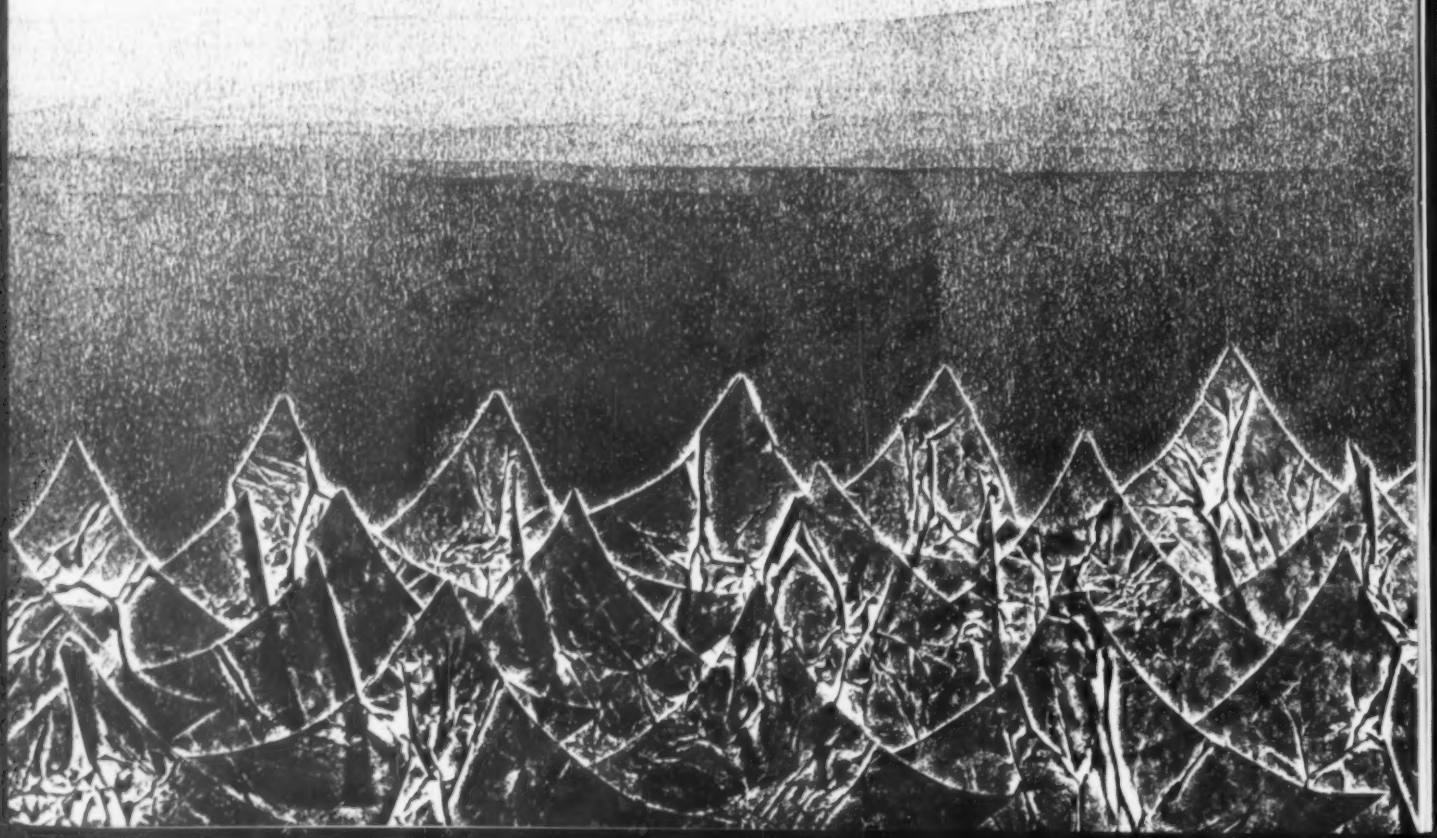
Mowbray Company

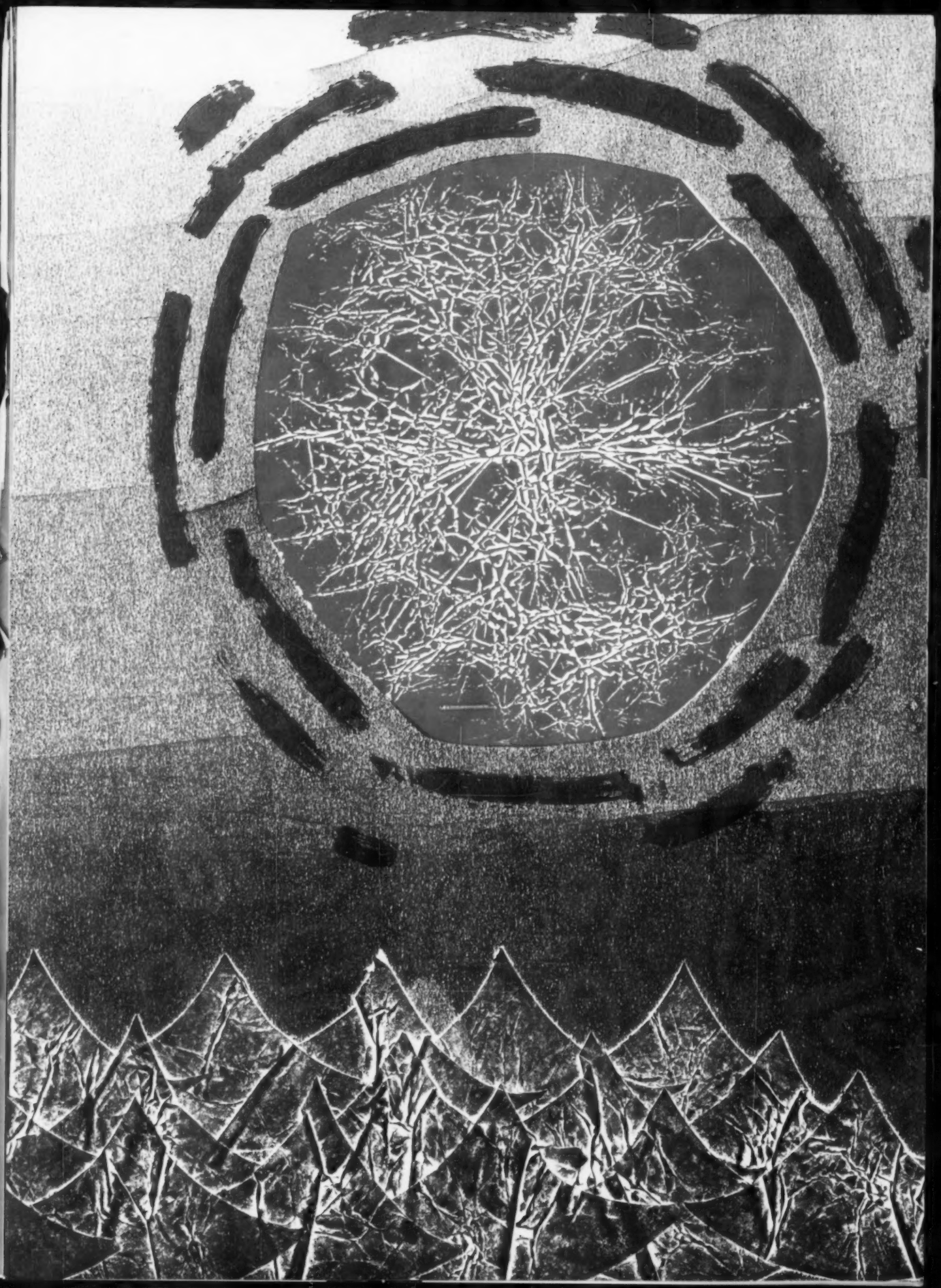
23 PECK STREET
PROVIDENCE, RHODE ISLAND
Telephone UNion 1-1000

by **Asa E. Snyder,** *vice-president, Pratt & Whitney Co. Inc.*

THERMAL ENERGY OF THE SEA

With the increasing demand for energy and water in underdeveloped nations striving for industrialization, the utilization of thermal energy locked in the earth's seas becomes of more than academic interest. ◁ The ocean and the earth's atmosphere form a gigantic heat engine whose fuel is the sun. Basically, the thermal energy of the sea is latent solar energy that has been stored within large bodies of water upon the earth's surface and is maintained in equilibrium with the atmosphere by constant replenishment from the sun. ◁ In the oceans of the world, huge volumes of water that have been heated by solar radiation to a relatively low thermal level exist at or near the surface of the ocean. Surface water temperatures of 80 F or more are quite common in tropic regions. On the other hand, at relatively shallow depths in the ocean of no more than 1,200 feet, sunlight does not penetrate, and ocean water temperature is 40 F or less. ◁ Based upon the requirements of thermal power cycles, we know that any sea thermal energy conversion





system requires: a source of heat (hot body); a receiver of heat (cold body); a working medium; a means of abstracting or adding heat; and a method of producing work.

The temperature difference between the surface and depths of the seas can be utilized as the source and receiver respectively, and is therefore a potential means of obtaining almost unlimited amounts of energy. The water itself can be used as a working medium, and only an economical and practical means for extracting work is required.

A brief history

Initial impetus to the study of sea thermal energy was given by Georges Claude between 1925 and 1935. Claude carried out tests on the installation of a submarine cold water pipe from a coastal power station in Cuba, and of a vertical submarine cold water pipe beneath the floating "Tunisia" power station. The accomplishments of his experiments were:

- Successful operation of a steam turbine with a difference of 27 F.
- Design of an efficient air extractor.
- Demonstration of problems in protection from wave action while laying the cold water inlet pipe in the open ocean.

In 1941, the French government created an interministerial organization to continue Claude's research. In 1948, a semi-official company, Energie des Mers, was formed by the French to carry out investigations in this field.

In the United States, the Office of Saline Water, U.S. Department of Interior, has sponsored design studies of flash-type evaporators that might utilize energy in bodies of water. Basic studies were conducted under the Sea Water Conversion Program at the University of California.

The United Nations Economic and Social Council has stimulated continued interest in this subject through support of writings and findings of specialists with international reputations in this field. Interest and work on this form of conversion is active in the United States, France, Israel, and Chile.

Problem: cost and size

The principle of the thermal-difference engine is relatively simple. Components consist of known and tested hardware, and extensive developments are not required to put one of these plants into action. Size of the installation and, accordingly, size of the initial capital investment until now have been the main retarding factors in preventing rapid adoption of the principle.

I-R's entire January issue will be devoted to a forecast of the size and shape of R&D and its changing economic role in 1962.

The excellent work conducted by Energie des Mers engineers under the direction of Christian Beau has demonstrated the feasibility of laying large-diameter pipes along the sea floor to obtain cold water supplies. Obviously a sizeable effort is required to lay a pipe of this magnitude at great depths for large distances.

A simple temperature entropy diagram for water is shown in fig. 1. Cooling the temperature of water vapor already heated to 80 F (point 1) to 40 F (point 2) lowers the vapor pressure to that obtainable at 40 F. Vapor pressure at 80 F is 0.5069 psia, whereas vapor pressure at 40 F is 0.1217 psia. Thus we have a small but decided pressure drop that can be used to extract power from the seas.

Simplified system

A simplified basic system for extracting sea thermal energy in the form of useful mechanical work is shown in fig. 2.

Heated surface water is led into a chamber where the water is evaporated at the higher temperature. This chamber is connected to a turbine, which extracts mechanical work as the pressure drops through the turbine. Exhaust from the turbine enters a condenser where the vapor is condensed into liquid.

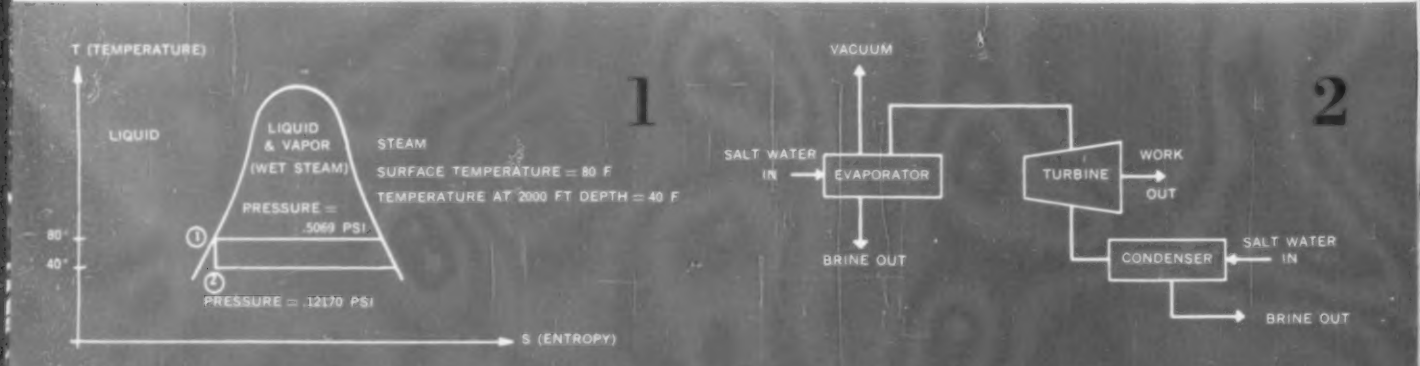
When power alone is an important or primary consideration, a mixing type condenser, where the cooling water and vapor mix together prior to being discharged, can be utilized as shown in fig. 3

In order to obtain fresh water as a byproduct from the plant, a surface type condenser is utilized. Several other cycle configurations can be envisioned. Although all are basic derivatives of the cycles above, they show great promise for reducing size and cost of the initial investment.

The oceans' reservoir

It is important to realize the extent of the oceans' reservoir of thermal-difference energy. Ocean waters cover 70.8% of the earth's 196,950,000 sq miles of surface, but the amount of land in the Northern Hemisphere is 39.3%, or more than twice that in the Southern Hemisphere (19.1%). Water covers only 60.7% of the former and 80.9% of the latter.

Between latitude parallels of 45 degrees N and 70 degrees N, land exceeds the water surface, whereas between 35 degrees S and 70 de-



Sea's thermal energy (1) can be harnessed to a shaft (2);

grees S, land forms only a small part of the surface.

Another important consideration is the general distribution of surface temperatures of the ocean shown below:

SURFACE TEMPERATURES OF THE OCEANS

Degrees of Latitude	Atlantic	Pacific	Indian
70-60 N	42°F	—	—
50-40 N	55°	50°F	—
30-20 N	75°	74°	79°F
10-0 N	80°	81°	82°
10-0 S	77°	79°	81°
30-20 S	70°	70°	72°
50-40 S	48°	52°	48°
70-60 S	34°	34°	35°

The table shows that the 70 F climate falls within the belt of 20 degrees north and south latitudes. Also, oceanographers have long known that temperature variation in a vertical plane in the ocean varies over the face of the earth.

The upper layers of the sea therefore are at a considerably higher temperature than the lower ones. A few exceptions exist to this rule, of course, particularly at the great latitudes and near the sea bottom at very low depths. Yet the rule is fairly consistant for small and average latitudes.

The vertical temperature gradient is even more noticeable in tropical seas where temperature differences between the surface and depths reach 40 F. Thus at 1,200 ft or more, the temperature begins to be sufficiently low with minimal variations in almost all oceans, thereby providing a constantly reliable thermal-difference reservoir.

Inasmuch as a minimum thermal difference of 30 F probably is required for economical utilization, feasibile installations of sea thermal energy plants are established by the world's water temperature distribution.

The 'thermal-difference' belt

Since the 70 F surface temperature climate falls within the belt of 20 degrees North and South latitudes, the water area (70.8%) is a sizable percentage of the earth's surface within this range. For the sake of convenience, the area within these latitudes may be termed the "thermal-difference belt."

Each day the earth receives on each square foot of its upper atmosphere more than 10,000 Btu of solar energy. Because the atmosphere absorbs some of this energy, and because sunlight strikes the earth's surface less than half of each 24 hours, only about 3,000 Btu reaches sea level. This is equivalent to approximately one kilowatt-hour per square foot per day. Assuming a loss of 40% due to weather, the average value of solar radiation at sea level is approximately $4 per sq ft per year at two cents per kilowatt-hour.

Approximately 47,300,000 sq miles, or 13.8-quadrillion sq ft, of water are located within the thermal-difference belt. In this belt alone, the average value of solar radiation received at sea level is a staggering sum: $52.7-quadrillion!

Assuming an average value of solar radiation absorbed by sea water to be not more than 20%, we find that a supply of free energy is given each year to the earth's water surfaces in tropical and semi-tropical areas equivalent in dollar value to $10.5-quadrillion. If the fossil-fuel-lacking underdeveloped areas of the world, which fortunately are within the thermal-difference zone, were to use but a small percentage of this available power, the problem of their industrialization would be solved.

Sea thermal energy has collected cobwebs for too long, and it is time that world leaders gave it some consideration, believes Asa E. Snyder, Pratt & Whitney vice-president and research director. Snyder's interest in sea thermal energy stems from his affiliation with U.S. Industries Inc., where he directed the research activities of the first American engineers to work in this area.

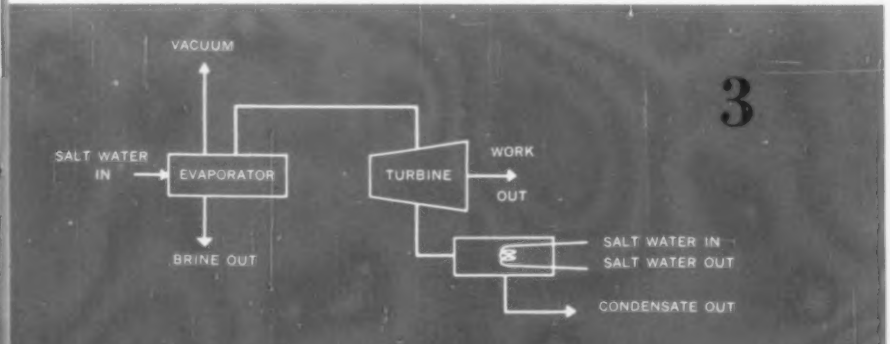
$369-trillion of energy

From a Carnot cycle analysis (see Oct. I·R) of the temperature range of the thermal-difference belt, it can be shown that approximately 7% of the total energy can be converted ideally into thermal energy. Assuming overall efficiencies of any conversion system to be about 50%, then more than $369-trillion of equivalent energy would be available to the nations in the thermal-difference belt. In other terms, this is equal to 92-trillion kilowatt-hours of power, or about 131-billion tons of coal per year. Of course, only a small percentage of this reservoir of available energy can be utilized fully.

The absolute minimum energy required to separate 1,000 gallons of fresh water from sea water is 2.9 kilowatt-hours, regardless of the type of conversion process. That minimum requirement, however, is for an ideal process, and is merely the minimum amount needed to tip the scale of the vapor pressure equilibrium. The resulting evaporation would proceed at a barely precipital rate.

In practice, the separation of water from salt takes up to 1,000 times the amount of energy given as the theoretical thermodynamic requirement (the expenditure of Btu of heat per pound of water, or, about 2,800 kilowatt-hours of energy in the form of heat per 1,000 gallons of water). Some other processes reduce the energy requirements to only about four or five times the thermodynamic minimum or about 10 to 15 kilowatt-hours per 1,000 gallons.

Assuming for the sake of discussion that a process could be devised



used to generate power (3) or both.

Industrial Research says
Merry Christmas twelve times a year

when it's your choice for the technical or management man on your gift list, or for a unique Christmas gift to yourself. For something of unique value to scientific and management men who constantly must be aware of what's going on, you need travel no farther than your armchair to send them Industrial Research at the special holiday rates. Speed your holiday greetings in a way that will be repeated and appreciated throughout the year. Gift cards will be sent to those you specify, shortly before Christmas.

INDUSTRIAL RESEARCH
Beverly Shores, Indiana

Please send _____ years of Industrial Research as my gift to:

_____
name of gift recipient

_____
company and position

_____
address

_____
city zone state

Sign gift card: *"From_____"*

Please send _____ years of Industrial Research as my gift to:

_____
name of gift recipient

_____
company and position

_____
address

_____
city zone state

Sign gift card: *"From_____"*

Special Holiday Offer

1 year (12 issues)	$ 6
2 years (or two 1-year subscriptions)	11
3 years (or three 1-year subscriptions)	14

☐ check enclosed ☐ bill me later

_____
my name

_____
address

_____
city zone state

Here's a brief rundown on what's in store for Industrial Research readers next year:

The entire January issue will be devoted to a forecast of what to expect from the research industry in 1962. Separate articles will point out new developments, trends, and money to be spent on research in aerospace, applied mechanics, chemicals, electronics, instruments and computers, metallurgy, and nuclear energy. We will be talking about growth, new facilities, applications, frontiers, problems . . . all keyed to helping technical management in the man-killing task of planning and marketing R&D.

I•R's previous forecasts have been remarkably accurate. The I•R Forecast Issue will do more than reach your desk. It will stay there.

February, March, April, and May issues will be filled with controversy— "Compensating the Innovator," "Has Research Been Oversold?" management use articles— "Where and How to Build a Research Laboratory," "Protecting Patents" and story after story designed to bring readers up to the state-of-the-art in such areas as solid state physics, superconductivity, data recording, radiation, materials, photography, and many others.

The June issue will be the special annual $2 reference edition entitled "Revolution in the Tools of Research." The lead article will be a carefully developed, fast-reading survey on "Trends in Research Tools." State-of-the-art articles will cover such areas as Isotopes, X-Ray Analysis, Simulation, Computers and Man as Research Tools.

The trends in research, the applications of research, the controversies of science and management will be discussed every month throughout the year. No other publication has given readers so much editorial meat as Industrial Research, the technical magazine for management.

which requires no more than 100 kilowatt-hours per 1,000 gallons, the conversion of the total available energy within the thermal difference of the sea would permit the annual distillation of more than 920-trillion gallons of distilled water.

Free power for industry

The basic problem confronting leaders, engineers, and those responsible for planning and development of underdeveloped countries within the thermal-difference belt is the feasible harnessing of this abundant free energy.

The countries or areas of the world which can expect to use this type of sea water conversion and energy conversion include: Central America and the Caribbean Islands; northern and central coasts of East and West South America; west coast of Africa from Mauretania south to the Congo; east coast of Africa from Somaliland south to Madagascar; south coast of Arabia; Ceylon, Indonesia, New Guinea, and Borneo; the Philippine Islands, Taiwan, and Australia.

Practically none of these areas is self-sufficient in fossil fuels, and in many of the nations fresh water and fuel are major deterrents to further industrialization. But the countries within the thermal-difference belt could free themselves from their dependence upon other economies for fuel by tapping the thermal energy of the seas, thereby conserving or balancing their monetary exports and hastening their own industrialization.

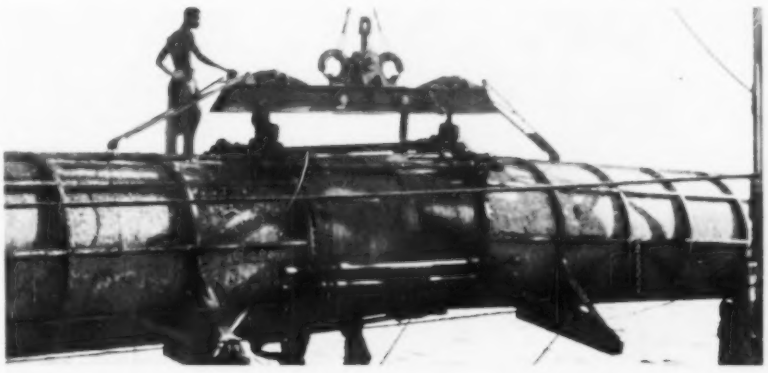
One of the major considerations for plant location is the local geology. The power plant must be close to deep water which has unrestricted communication with the oceans. A steep shore—such as that usually found along a volcanic or coral island, spits of land, natural peninsulas, or bars of river-borne silt—is desirable. If at all possible, a nearby submarine canyon at right angles to the shore line is desirable.

Texas-tower type plant

A sea-based station built like a Texas tower, with a submarine cable and pipeline for power and water transmission, also is feasible. The reduction in cost of the expensive cold water intake pipe would compensate partially for the higher cost of the sea-based station. This type of plant is considerably less influenced by geological considerations and eliminates a dependency upon submarine canyons or the close proximity of drops to the shoreline.

Since no full-scale industrial thermal-difference plants have been constructed, economic considerations are of primary importance in evaluating this form of installation. Investigators have shown that the cost per installed kilowatt against plant size compares favorably with installed costs of fossil-fuel thermal-power plants in underdeveloped areas. When returns on both power and water are considered, the thermal-difference energy and water conversion plant is one of the most intriguing and promising for many areas of the world. ■

EXPERIMENTAL COLD WATER INLET PIPE, *developed by French engineers, is shown during tests at Abidjan, West Africa. The sea thermal energy research was conducted by Energie des Mers, a semi-official company formed by the French government to carry out investigations in this field.*



Industrial Applications of the Exotic* Metal Columbium

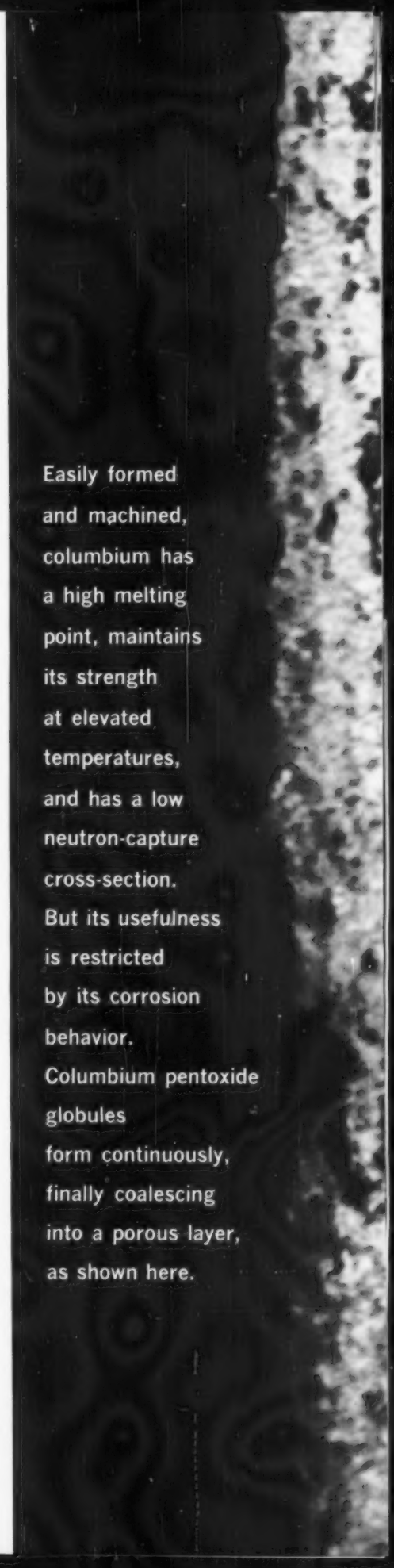
THE SEARCH FOR NEW MATERIALS to meet the very high temperature requirements of an advancing space technology is focusing on columbium, one of the so-called exotic metals, and its alloys. Because of its strength and corrosion resistance at high temperatures, columbium is showing great promise as a structural material for space vehicles requiring re-entry and in atomic energy applications. The metal also is helping to reduce costs and to solve complex commercial problems.

For example, a 20-gallon, full-hour emergency supply of oxygen, previously available only in large, unwieldy 125-lb cylinders, now can be obtained in 2-lb containers only 4 in. round for use in doctors' offices and automobiles. This size and weight reduction resulted from the use of a columbium bearing steel developed by National Steel's Great Lakes Steel Corp., Detroit, after six years of research.

The same family of columbium steels now are finding applications in gas pipelines. Vitally interested in any technological development that will offer more capacity per ton of steel per dollar invested, the pipeline industry has found that higher strength line pipe offers more opportunity for increased profits. This stronger pipe permits higher operating pressures resulting in more gas being moved with a reduction in cost.

When additional pipeline capacity is not a major factor, the same strength pipeline can be fabricated with thinner steel. The slight premium cost of columbium steel easily is offset by the saving in material. In addition, columbium steel's good formability and weldability characteristics facilitate the fabrication of pipeline sections in the shop. Even more important, columbium bearing steel requires neither pre-heating nor the related processes required by other steels when field-welded at below-zero temperatures. In this respect alone, one pipeline company calculates that it will save more

*ex-ot-ic—*strangely beautiful or enticing, foreign, or imported. However, columbium was named after the United States (Columbia), where it is found in plentiful quantities.*



Easily formed and machined, columbium has a high melting point, maintains its strength at elevated temperatures, and has a low neutron-capture cross-section. But its usefulness is restricted by its corrosion behavior. Columbium pentoxide globules form continuously, finally coalescing into a porous layer, as shown here.

than $150,000 on a new project.

The automotive industry is another area where this high-strength steel is finding wide application in frames and structural parts. Changing design and the necessity for cost reductions partially account for the auto industry's interest in columbium steel. By combining proper design with the use of columbium steel, a reduction in steel of as much as 35% can be realized. A truck's payload can be increased by reducing its empty overall weight, thus providing a material saving to the manufacturer, as well as an increased payload to the user.

Columbium also increases killed steel's resistance to brittleness at much lower temperatures than with mild carbon steel for important applications in earth moving equipment used in northern climates where work must proceed during the winter months.

Ferro-alloys of columbium have been used for many years as stabilizers in stainless steel to prevent

by **Marx Hirsch,** *president, Molybdenum Corp. of America*

THE UBIQUITOUS AROCLOR® "GENIE" DOES IT AGAIN!

SECRET OF THE SORCERY?

Utter inertness! The Aroclor chlorinated polyphenyl compounds *(12 of them)*, ranging from water-white liquids through viscous oils to bright-yellow solid resins, are just about the most *unreactive* materials ever synthesized. They stubbornly refuse to volatilize, oxidize, hydrolyze, harden, disintegrate, burn, condense, or corrode *anything!* Use them *"per se"* as lubricants, dielectrics, reaction media, heat transferants.

SOURCE OF THE SECRET?

A wondrous booklet, "THE AROCLOR COMPOUNDS"—44 pages of meaty information sure to give you ideas for a host of product improvements and money-savings. Write today for your copy.

IN COATINGS—
Aroclor *liquids* flexibilize; Aroclor *resins* increase film hardness. Either form increases chemical, heat, moisture, and weather resistance; promotes better adhesion to substrate.

Do not react with oils or solvents and can be used as diluents, thinners. Compatible with practically all commercial film formers and cheap enough to save money on formulation.

and

IN HOT MELT and PVAc ADHESIVES—
an Aroclor imparts a bull-dog bite to the quick tack, can tailor the hardness of the adhesive when set. While imparting a *"just right"* flexibility to any adhesive's resin base, an Aroclor increases bonding strength and imparts resistance to moisture, acids, alkalis; inhibits corrosion and microorganism attack.

and

Write Today for this 44-Page Booklet

MONSANTO CHEMICAL COMPANY
Organic Chemicals Division
Dept. 4470-K, St. Louis 66, Mo.

Monsanto

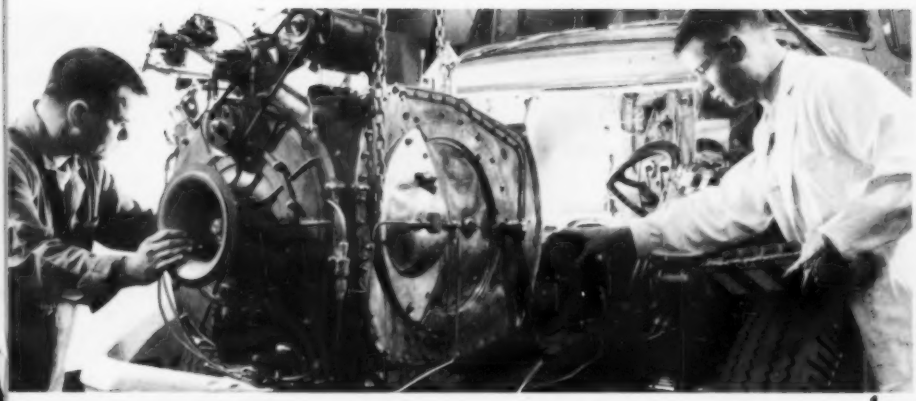
COLUMBIUM ALLOYS *are finding wide application in the automotive industry for the fabrication of frames and structural parts, and will find increased use in gas turbine engines, the components of which are subjected to greater temperatures than ordinary piston engines. An experimental gas turbine engine (1) is installed in a truck at General Motors Research Labs for road tests. Because of columbium's low neutron absorption, seamless columbium tubing (2) developed by Fansteel Metallurgical Corp. is being studied for nuclear reactor applications. Ready fabricability and a good strength-to-weight ratio at elevated temperatures makes columbium sheet suitable for cold spinning of rocket nozzles (3) at Fansteel. Processing of columbium alloys is being studied by both government and industry. Molybdenum Corp. of America uses an electric furnace (4) to produce columbium ferro-alloy.*

carbide precipitation in the 800 F to 1600 F range. Small percentages of columbium are being added to type-435 stainless steel, used for decorative purposes, to prevent roping or surface imperfections when polished.

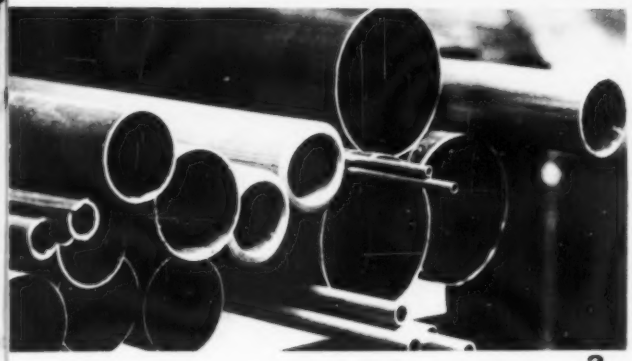
New uses for pure columbium

Although the major potential immediate market for columbium probably lies in columbium bearing steel, pure columbium is finding use in the electronics industry as a getter and electron emitter in tubes. In addition to its ability to absorb and hold residual gases when heated, the metal offers a high melting point, ease of fabrication, and efficient thermionic electron emission.

A new type of miniature electronic valve, the cryotron, consists of a fine columbium wire wrapped around a tiny strip of tantalum. This combination becomes superconductive in a liquid helium bath at about minus 450 F. A cryotron has a considerably lower power consumption than a thermionic valve and is so small that a hundred of them fit into a thimble! The component offers exciting possibilities for computers and radar devices.

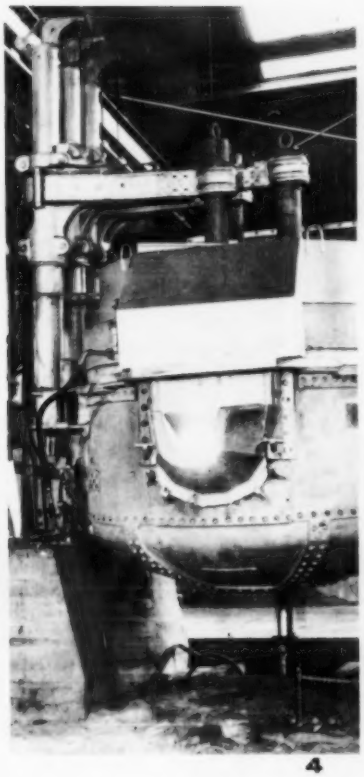


1



2

3



4

Columbium carbide is used separately or blended with tungsten and tantalum carbides and cemented with cobalt metal for use in hot forging dies, cutting tools, jet engine turbine blades, valves, valve seats, valve guides, and for coating graphite rocket nozzles.

Work now underway strongly indicates that columbium also will be used in any future gas turbine motor car. Experimental gas turbine engines using blades made of columbium will operate at 2500 F. Columbium is particularly suitable since these components are subjected to greater temperatures than parts in the ordinary piston engine.

British Standard aluminum casting alloy specifications call for columbium. The metal acts as a grain-refiner in these alloys when it is used in cylinder blocks and crank cases. The development of the aluminum cylinder block will be a major factor in the use of columbium by the automotive industry.

Unraveling the nomenclature

A pencil-gray lustrous metallic element about as hard as copper, columbium was first discovered in 1801 by an English chemist, who named the metal columbium in honor of the country from which the ore originated, the United States (Columbia). The following year a Swedish chemist isolated what he thought was a new element and named it tantalum, because of the way it *tantalizingly* kept its identity from grasp for many years and in honor of a mythological Greek god.

In 1844 still another experimenter determined that the material discovered by the Swedish scientist actually was a mixture of two elements, and named the second *niobium* in honor of the daughter of the first Greek god. Twenty-two years later it was discovered that columbium and niobium were the same element, and to this day the double nomenclature persists.

Prior to 1955, commercial development of columbium was hindered by lack of adequate ore reserves, government restrictions, and high extraction costs. Government pressure and guaranteed purchase plans encouraged expansion of existing production and resulted in the discovery of new ore reserves. Availability of new supplies encouraged interest in columbium and metallurgical groups started to work seriously to develop uses for this "new" metal.

Properties for exploitation

Columbium has five key properties that interest metallurgists and scientists.

- *High melting point* — Columbium has a melting point of 4470 F. Although this is not the highest among metals, it is high enough to assure that alloys of the metal can be developed with useful strengths up to 3000 F.
- *Good intrinsic ductility* — The relatively pure metal can be cold-rolled and has an impact transition temperature below 100 F. Unlike other refractory metals, except tantalum, it is insensitive to interstitial impurities.
- *Reasonable chemical inactivity* —Columbium metal is resistant to many acids and to liquid metals. It is not very resistant to hot air (about 1200 F), but still is one of the three most oxidation-resistant refractory metals. Columbium can take temperatures over 1700 F before corrosion starts.
- *Low capture cross-section for thermal neutrons* — Columbium is the best of the refractory metals for

Christmas every Wednesday

Christmas 52 times a year . . . The Research Trendletter Weekly is the perfect gift for the scientific or management man who already has nuclear reactors, spectrophotometers, and his own airplanes.

Loaded with vital information, edited for rapid assimilation, the Research Trendletter Weekly will be received each Wednesday of the year.

If he is among the I·R readers who regularly turn to the Trendletter section in the magazine, he will be interested in the weekly service. The weekly Trendletter will be similar to the magazine section, but in addition will • keep him appraised of competitors' latest developments • relate news of defense and industrial contracts to their possible impact on his company and on the stock market • present applications of research in product development *weeks* before they appear in the technical press • point up trends in scientific research and technical advancement • describe what acceptance a new development is likely to have, and what project or process it might render obsolete • provide an idea file (three-ring punched) complete with source information.

The Research Trendletter Weekly will do all these things every seven days—arriving *air mail* with Tuesday's development news the morning of *every Wednesday*.

Here is our Special Pre-Publication Christmas Gift Offer: you can send the Research Trendletter Weekly for only $50 annually—a savings of $25 a year . . . you may also include a subscription for yourself at this same special holiday rate.

send Christmas gift cards for a one-year subscription (52 issues) of Research Trendletter Weekly to the following:

name

address

city, zone, state

company and position

sign gift card "*from*_____"

name

address

city, zone, state

company and position

sign gift card "*from*_____"

send bill to:

name

address

city, zone, state

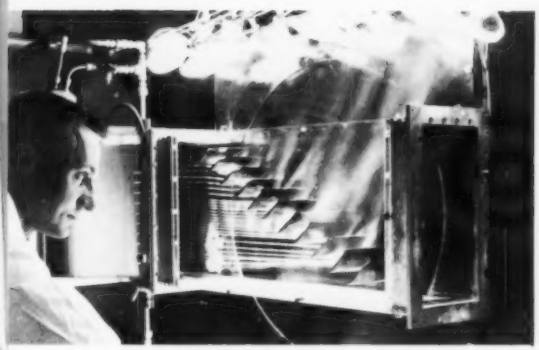
company and position

RESEARCH TRENDLETTER WEEKLY BEVERLY SHORES, IND.

☐ also please enter my own personal one-year subscription at the same Christmas gift rate of $50 per year.

☐ *check enclosed* ☐ *bill me later*

If check is enclosed, saving us billing, you are entitled to receive a full year (12 issues) of Industrial Research magazine FREE, as an additional bonus.



GAS TURBINE *automobiles of the future will require columbium alloys for the fabrication of combustion chambers, turbine blades, and other parts subjected to extremely high temperatures. Typical is the gas turbine compressor shown here undergoing smoke tests at General Motors Research Laboratories.*

this property, important in nuclear reactors.

■ *Low density* — Columbium's density is 7.87 grams per cubic centimeter, which is just about that of iron, and is the lowest among the refractory metals. This is important for applications where weight and strength are a problem, such as in airplanes and spacecraft.

Of particular interest to technologists is that it is comparable with mild steel in its ability to be drawn, stamped, or formed. Columbium work-hardens at a much slower rate than most other metals, and reduction in thickness of 60% or more, without intermediate annealing, is standard practice. Columbium can be welded to a number of other metals by either resistance or inert-gas arc welding methods, and can be welded to itself by arc welding. However, oxygen and other common gases must be excluded from the weld zone.

Probably the most important step in the growth and interest in columbium has been the recent development of columbium bearing steels. The addition of from only a half to two pounds of columbium per ton of steel increases the yield strength of carbon steel to the range of from 45,000 to 60,000 or more pounds per square inch, and the tensile strength to 65,000 to 80,000 psi, depending on several factors including the amount of ferro-columbium added. The exciting properties of this increased strength steel include formability and weldability (with no underbead cracking) of regular carbon steel.

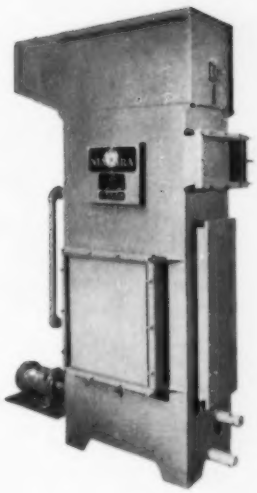
A metallurgical nightmare

Processing problems were of major magnitude in the early stages of columbium's development. No standard set of processing methods exists for all alloys of columbium, primarily because of the wide variation in properties. Many of the processing problems are being solved by government and industry research programs. The Air Force, Naval Research Laboratory, and Atomic Energy Commission are studying the properties of columbium and new alloying methods because of the potential use in future manned spacecraft.

One solution to the problem of columbium alloy processing has been achieved by Fansteel Metallurgical Corp., North Chicago. In collaboration with Armour Research Foundation, Chicago, Fansteel has developed a process for the direct addition of high purity columbium to metals by exothermic reduction. In the process, columbium oxide is blended with a reducing agent (either aluminum or calcium silicon) and compacted into pellets.

When reacted, the aluminum type liberates essentially pure columbium, and the calcium-silicon type liberates an alloy of silicon and columbium of substantially lower melting point than pure columbium alone. Therefore this alloy disseminates throughout the molten bath

A leading figure in metallurgy for almost 50 years, Marx Hirsch was instrumental in the design and construction of the first rare earth metal plant in the United States (in 1916 when rare earths were considered laboratory curiosities). He has been associated with Molybdenum Corp. of America and its predecessor since 1915, becoming company president in 1930. Hirsch is a fellow of the American Institute of Chemists.



The AIR CONDITIONER you can really TRUST FOR ACCURACY

Hundreds of critical processes and testing procedures with hygroscopic materials have proven the NIAGARA "Type A" to be the one conditioner that is truly reliable over long periods.

It performs these duties:

- **Maintains temperature and humidity constant to tolerances of 1° F and 1% R. H.**
- **Changes temperature and humidity as required in a range not afforded by other apparatus.**
- **Furnishes either heating or cooling.**
- **Provides moisture or dryness in any desired proportion to air for Processing.**
- **Cleans, deodorizes and purifies the air.**
- **Assures the air movement desired.**

NIAGARA "Type A" is the small machine that does a big job, giving you a third to a half greater cooling capacity for its size than conditioners that do not achieve saturation of the air. Thus it has unequalled flexibility, absorbing sudden peak loads and atmospheric changes, holding its required conditions, protecting your valuable materials or your critical processes from loss or damage. Its operating range, using Niagara "No-Frost"® liquid below the freezing point of water is through 140° F. Many Niagara units have given this precision for twenty long years of service.

Write for bulletin 58 and 122.

NIAGARA BLOWER COMPANY

405 Lexington Ave., New York 17, N. Y.

Niagara District Engineers in Principal Cities of U. S. and Canada

DEPENDABLE ACCURACY
Wavelength: 5A
Photometric: 0.005 at 4A

CRITICAL REPEATABILITY
Wavelength: 2A
Photometric: 0.003

PRACTICAL WAVELENGTH RANGE
200mμ-700mμ

CONSTANT NARROW BAND PASS
Standard: 5A and 50A
Special order: 2A and 50A

LOW STRAY LIGHT
0.1% at 220mμ

RAPID SCANNING
6 different speeds, from approximately 1 minute to 10 minutes

How much should you pay for a recording spectrophotometer?

$3685, for pinpoint coverage of the visible range. $4285 for visible *and* UV.

You might pay a little less, but at the cost of recording speed, accuracy, repeatability, and range of application. You could pay more than twice as much, but you still wouldn't get such exclusive Spectronic 505® advantages as automatic wavelength speed control and the built-in mercury lamp for checking wavelength calibration.

The Spectronic 505 provides high-speed, high-precision recording of transmittance, linear absorbance and emission—*plus* accessories for reflectance between 400-700 mμ. The only other instruments that can approach its speed, accuracy and simplicity cost from two to four times more. That's why the Spectronic 505 has become the best-selling spectrophotometer of all time.

BAUSCH & LOMB INCORPORATED
81324 Bausch Street, Rochester 2, New York

☐ Please send me Spectronic 505 Catalog D-2009.
☐ Send Booklet D-2019, "Fundamentals of Spectrophotometry."

NAME, TITLE .....
PROFESSIONAL ADDRESS .....
CITY ..... ZONE ..... STATE .....

BAUSCH & LOMB
SINCE 1853

Made in America, to the world's highest standards.

with considerable ease.

Yet, many more problems remain to be solved before columbium's full potential can be realized. Columbium fabrication and working is affected by several characteristics of the metal. When hot, the metal absorbs gases that cause embrittlement. All forming, stamping, and drawing must be done cold or in an inert atmosphere. The metal also sizes and tears easily so that caution must be used in machining.

Workability plus strength

Among the more pressing problems are a method of making mill products of columbium and the development of a coating or an alloy that will prevent oxidation at high temperatures, without affecting ductility and fabricability. The latter is very important to missile, nuclear, and jet applications of columbium.

During the past year considerable research has been done to find a combination of metals that would exhibit workability while showing strength and corrosion resistance over a wide range of temperatures. Some promising reports have been made on new experimental alloys, most of which combine columbium or tantalum with one or two other refractory metals. Unfortunately, the metals used as alloying agents to reduce oxidation of columbium tend to decrease ductility and fabricability.

The basic problem then for metallurgists is to find the correct materials and combinations that will achieve oxidation resistance while not sacrificing too many of these needed mechanical properties. Perhaps a combination of alloying and coating will produce the best results and solve the oxidation problem.

A new family of columbium alloys that reportedly exhibit the best balanced combination of properties yet achieved with this metal has been announced by Westinghouse Research Laboratories in Pittsburgh. Research and development leading to the alloys was performed, in part, under contract with the U.S. Air Force Directorate of Materials and Processes, Aeronautical Systems Div., Dayton, O. High strength at high temperatures is attained without drastic loss in the workability and low-temperature ductility inherent in the pure metal itself.

The trends of application

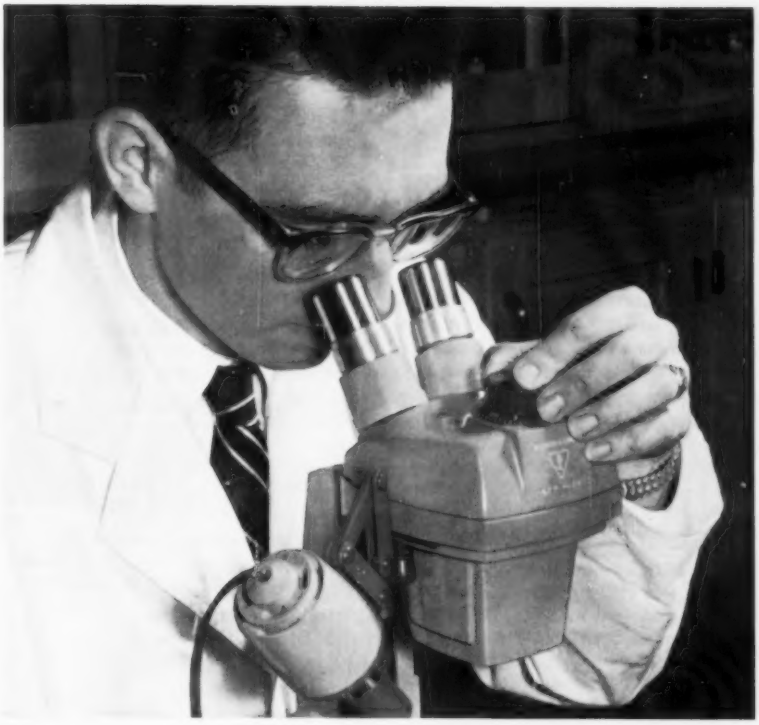
Based on present indications and research results, it seems probable that columbium in the next decade or sooner will find wide acceptance in many important areas. The increased use of columbium bearing steels will be the area of development realized soonest. Once engineers combine proper design with the use of columbium carbon steel, they will find many practical, cost-saving applications.

As for the pure metal, or alloys of it, there are a great many potential uses. Most nuclear reactors utilizing liquid metal as the coolant eventually will use columbium. One of the first applications may be in jet aircraft engines. Present materials are good only up to 1800 F to 2000 F range. When today's engines are redesigned to higher operating limits, in the neighborhood of 2400 F, columbium probably will be the metal most used for combustion chambers, turbine blades, and other parts subject to the extremely high temperatures required.

Columbium will be used in increasingly larger quantities in most new spacecraft, satellites, and missiles in a variety of components and even possibly for the skin of these vehicles.

Columbium also has a potential for gas turbine engines designed for stationary power applications and heavy construction equipment. It will be used in the construction of chemical industry corrosion resistant process equipment. Aircraft nuclear reactors and aircraft landing gear are other future applications.

The potential for columbium, columbium alloys, and columbium carbon steel is large. Technologists must come up with uses for columbium by applying "development thinking." That is, they should study the properties of columbium, columbium alloys, and especially columbium carbon steel, and integrate these properties into their own product or problem. Then by adjustment, slight change in design, or composition and adaption, they will arrive at a product that will meet the needs of their industry. The future is bright, the product is available in abundant supply, and its properties are excellent. All that is necessary is its application. ■



Why you need both

ZOOM and 3-D

for thorough inspection

Zoom microscopy gives you the exact magnification for each specific inspection need, from big area scanning at lower powers . . . to critical area examination at higher powers . . . to whatever power best shows what you're looking for.

3-dimensional microscopy shows your work piece in depth and in natural position, upright and unreversed from left to right, just as it would be positioned to the unaided eye.

And only Bausch & Lomb StereoZoom® Microscopes give you Zoom and 3-D. See for yourself how this revolutionary new design can save on your inspection jobs by keeping work constantly in focus throughout the continuous magnification range ...available from 3.5X to 120X. Just mail the coupon now.

BAUSCH & LOMB
SINCE 1853

Made in America, to the world's highest standards.

BAUSCH & LOMB INCORPORATED
81624 Bausch Street, Rochester 2, N.Y.

☐ Please demonstrate StereoZoom Microscopes at my convenience.

☐ Please send Catalog D-15.

NAME .....

COMPANY .....

ADDRESS .....

.....

NCR National

ADVANCED DEVELOPMENT

Continued growth and lasting stability underline the excellent professional opportunities at NCR's Engineering and Research Center in Dayton, Ohio. Projects in progress require personnel for the following positions:

ELECTRONIC ENGINEERS — BSEE with 2 - 5 years experience with military electronic equipment. Familiar with ground based equipment development or airborne equipment development. Should have a background in one of the following areas: circuit design, logic design, electronic power supplies, electronic packaging, or test equipment design.

MECHANICAL ENGINEERS — BSME with 2 - 5 years experience in the design and development of mechanical assemblies and equipment. Should have a sound background in shock mounting and packaging of electronic equipment. Should be capable of following a developed package through the design and detail areas.

CIRCUIT ENGINEERS — BSEE with 5 - 7 years experience in the design and development of electronic equipment using solid state or vacuum tube circuits. Experienced at designing circuits for reliable operation under worst case conditions.

LOGIC ENGINEERS — BSEE with 5 years experience in the design and development of digital logic systems. Should be acquainted with methods of achieving reliable operation with minimum circuit elements.

COMMUNICATION SYSTEM ENGINEERS — BSEE with 5 - 7 years experience in the HF Communications area. Should have experience in long distance propagation techniques with particular emphasis on solution of multipath effects in the 2 - 30 mc range.

COMPONENT ENGINEERS — BSEE with 3 years experience in testing and evaluation of electronic components. Should be familiar with military component specifications and be knowledgeable in component selection.

Now is the time to revitalize your career with new and expanding opportunity. Write now to:
Mr. Thomas Wade, Technical Placement, The National Cash Register Company, Main and K Streets, Dayton 9, Ohio.

AN EQUAL OPPORTUNITY EMPLOYER

I·R ADVERTISERS' INDEX

Acme Visible Records, Inc. 8
Agency: Cargill Wilson & Acree Inc.

American Research & Development Corp. . . . . Cover 4

Bausch & Lomb Incorporated 9, 48, 49
Agency: Wolff Associates, Inc.

Bell Aerosystems Company 24
Agency: Comstock & Company Advertising

Bell Telephone Laboratories, Inc. . . 12
Agency: N. W. Ayer & Son, Inc.

The Cerand Corporation 52
Agency: Parsons, Friedmann & Central Inc.

Eastman Chemical Products, Inc. Plastics Division . . . . . Cover 2, 3
Agency: Fred Wittner Company

Hamilton Company, Inc. 28
Agency: L. J. Swain Advertising, Inc.

Keuffel & Esser Co. 11
Agency: O. S. Tyson and Company, Inc.

Lenkurt Electric Company A Subsidiary of General Telephone & Electronics . . . Cover 3
Agency: Kudner Agency, Inc.

Lowry-Preston Technical Abstracts Co. 51

Monsanto Chemical Company Organic Chemical Division 44
Agency: Gardner Advertising Company

Mowbray Company 35

National Cash Register Company 50
Agency: McCann-Erickson Incorporated

Niagara Blower Company 47
Agency: The Moss-Chase Company

San Antonio Development Committee 51
Agency: Claude Aniol & Associates

Scientific Development Corporation 28
Agency: Jerome O'Leary Advertising Agency

Tektronix, Inc. 10
Agency: Hugh Dwight Advertising

Westinghouse Electric Corp. Semiconductor Dept. 6, 7
Agency: McCann-Erickson Incorporated

and I want . . . a recording spectrophotometer, and a neutron source . . . and a centrifuge . . . and a tunnel diode kit . . . and an anti-gravity machine . . . and . . .

I·R ADVERTISING SALES OFFICES

NEW YORK

Joseph F. Ryan, vice-president, Brushy Hill Rd., Darien, Conn., OLiver 5-9857.

John D. Curley, vice-president, 507 Fifth Av., New York 17, MUrray Hill 2-5333.

A. B. Murphy, 507 Fifth Av., New York 17, MUrray Hill 2-5333.

NEW ENGLAND

E. V. Burkholder, Providence, R. I.: 115 Butler Av., TEmple 1-0169; Boston: John Hancock Bldg., HAncock 6-7060.

PHILADELPHIA

W. J. McAllister, 64 Conwell Av., Erlton, N. J., HAzel 9-2545.

MIDWEST

Frank E. Landry, Beverly Shores, Ind., phone Chicago STate 2-4284.

LOS ANGELES

R. W. Walker Co., 730 S. Western Av., Los Angeles 5, DUnkirk 7-4388.

SAN FRANCISCO

R. W. Walker Co., 57 Post St., San Francisco 4, SUtter 1-5568.

INTERNATIONAL
(Great Britain, Europe, and Japan)

R. D. Miller, Pergamon Press Ltd., 4 Fitzroy Sq., London, W. 1, England, EUston 4455, Cable: PERGAPRESS.

IR EMPLOYMENT CLEARINGHOUSE

Positions wanted

COMMERCIAL ADVISOR TO TOP R&D EXECUTIVE to help you guide technically sound research programs toward realistic business goals. Thirty years of experienced judgment and informed imagination unravel the welter of technical and commercial forces which meet in the marketplace, providing realistic forecasts of sales potential and ultimate business success. Also, long-range planning and company acquisitions programs. Lucid reports and effective presentations in business English.

Box 208, Industrial Research, Beverly Shores, Indiana.

Consulting service

PHYSICO-CHEMICAL CONSULTANT will do original, exploratory devisement and evaluation of inventive concepts leading to research on new or improved processes and/or products. Extensive multilevel experience on chemicals, oil, gas, appliances, paper, color motion pictures, architecture, patents, license negotiation, specialties and private studies. Two degree man with process and journal reputation. Write without obligation.

Robert G. Wulff, Box 747, Evanston, Illinois.

CLASSIFIED RATES for this section are 50 cents per word, minimum 50 words. Count box numbers as six words. Closing date for both position-wanted and position-open classified ads to appear in the next, January, issue is Dec. 8. Checks must accompany insertions.

(Display ads also may be positioned in this section at regular display rates. For a rate and data card, write the Advertising Dept., Industrial Research, Beverly Shores, Ind., or call any of our sales offices listed on page 50.) ■

MEN and microscopes

RESEARCH If your business can use the help of research, consider San Antonio. Here is located one of the nation's largest contractual research centers . . . Southwest Research Institute with a staff of more than 500 scientists and technicians to help you test new products, improve established ones. Advanced research by the Center — and other San Antonio institutions: Aerospace Medical Center, Lackland and AFB Hospital, largest in the Air Force, and Brooke Army Medical Center, world's largest — have made San Antonio through research a science center of the nation for industry, space-travel, medicine and defense. Write today for more about how research and profits are partners in San Antonio.

City in the Sun

Greater San Antonio Development Committee
153 R Navarro St., San Antonio, Texas

San Antonio

Facts and figures everywhere . . .

But how can you find what you need when you need it?[1]

Information retrieval:
What will it do for the chemical engineer?[2]

How can scientists keep up with science?[3]

Did you see these articles? They all point up the growing problem of classifying and retrieving technical literature. Some of the solutions to this problem were described in the Wall Street Journal, December 20, 1964.[4] • The solution requires technical personnel, experienced in the use of libraries, having the ability to read all languages, and trained in the techniques of systematic literature searching. • The Lowry-Preston Technical Abstracts Company offers three services directed towards easing the information retrieval problem: (1) **Gas Chromatography Abstracting Service**—abstracts are issued of all articles involving gas chromatography. Covers literature of every country. (2) **Instrumentation Abstracts**—abstracts are issued of all articles dealing with laboratory and process instrumentation, as they appear in all of the principal journals dealing with this subject. (3) **Custom Literature and Patent Searching**—searches are conducted on any subject, to locate and summarize the books, periodicals, patents, government reports, foreign material, etc., published on the subject.

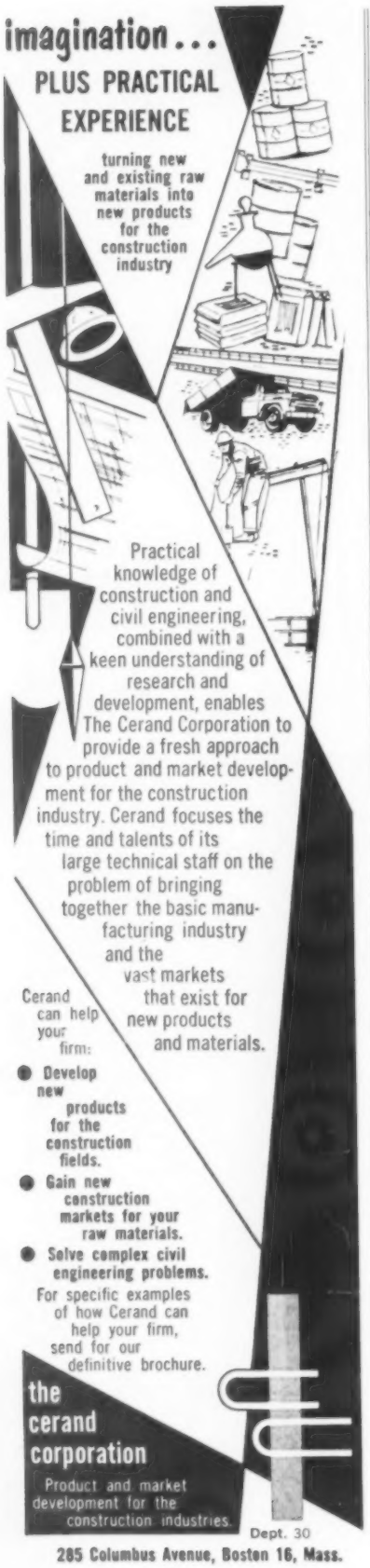
(1) *Chemical Processing, Dec., 1960, p. 29.*
(2) *Chemical Engineering, Dec. 26, 1960, p. 88.*
(3) *Address by E. V. Murphree before American Chemical Society.*
(4) *Fishing for Facts: Firms Add Specialists to Handle Rising Tide of Scientific Papers, Vol. XLI, No. 47.*

For further information, and to be included on the free mailing list of the Gas Chromatography "Newsletter," fill in this coupon and return to Lowry-Preston Technical Abstracts Co., Dept. C, 914 Chicago Av., Evanston, Ill.

NAME COMPANY

STREET CITY STATE

Please mark your area of interest:
☐ gas chromatography ☐ instrumentation abstracts
☐ literature searching


imagination...
PLUS PRACTICAL EXPERIENCE
turning new and existing raw materials into new products for the construction industry
Practical knowledge of construction and civil engineering, combined with a keen understanding of research and development, enables The Cerand Corporation to provide a fresh approach to product and market development for the construction industry. Cerand focuses the time and talents of its large technical staff on the problem of bringing together the basic manufacturing industry and the vast markets that exist for new products and materials.
Cerand can help your firm:
● Develop new products for the construction fields.
● Gain new construction markets for your raw materials.
● Solve complex civil engineering problems.
For specific examples of how Cerand can help your firm, send for our definitive brochure.
the cerand corporation
Product and market development for the construction industries.
Dept. 30
285 Columbus Avenue, Boston 16, Mass.

IR

CHECKLIST FOR MORE INFORMATION

NEW PRODUCTS

☐ RATED FLAG TERMINAL and flexible lead type controlled rectifiers are available for industrial, commercial, and military applications in high-frequency power generation, variable frequency controls, pulse generation, ignitron firing, and welding control. For additional information, write to: Westinghouse Electric Corp., Semiconductor Dept., Youngwood, Pa.

☐ AUTOMATIC WAVELENGTH speed control and a built-in mercury lamp for checking wavelength calibration are special features of a new recording spectrophotometer. Send for: Booklet D-2019 and Catalog D-2009, Bausch & Lomb Inc., 81321 Bausch St., Rochester 2, N.Y.

☐ CHLORINATED POLYPHENYL COMPOUNDS that will not volatilize, oxidize, hydrolyze, harden, disintegrate, burn, condense, or corrode anything, are available for use as lubricants, dielectrics, reaction media, and heat transferants. Write for booklet to: Monsanto Chemical Co., Organic Chemicals Div., Dept. 4470-K, St. Louis 66.

☐ AIR CONDITIONER that maintains temperature and humidity constant to tolerances of 1 F and 1% R.H. is available for critical processes and testing procedures with hygroscopic materials that require rigid atmosphere controls. Write for: bulletins 58 and 122, Niagara Blower Co., 405 Lexington Av., New York 17.

☐ JOB-MATCHED GRAPH PAPERS with grids and patterns evolved to solve specific needs can be obtained in a variety of stocks. Write for samples and graph sheet catalog and selection guide to: Keuffel & Esser Co., Dept. IN-12, Hoboken, N.J.

☐ PUSH-BUTTON RECALL and automatic selection are possible with an advanced filing concept for billing, research, customer service, personnel records, and other uses. For additional information, write to: Acme Visible Records Inc., 9412 W. Allview Dr., Crozet, Va.

NEW IDEAS

☐ PLASTIC PACKAGING RESEARCH has led to new applications of plastics for pipe to convey chemicals, coating burlap for military hutments to protect stored equipment, and for a miniature planetarium. For a booklet, write to: Eastman Kodak Co., Kingsport, Tenn.

☐ AEROSPACE TECHNOLOGY capabilities ranging from the development of rocket belts for earth travel to propulsion for moon probes are being offered to government and industry. For more information, write to: Bell Aerosystems Co., Buffalo 5, N.Y.

☐ NEED ASSISTANCE in developing new products for the construction fields or solving complex civil engineering problems? For examples of how you can obtain this help for your firm, write to: The Cerand Corp., Dept. 30, 285 Columbus Av., Boston 16.

I·R

INDEX TO VOLUME THREE (1961)

(Bold face type refers to titles of feature articles. Heavy numerals refer to issue numbers in Volume three; light numerals indicate page numbers. For index to: Volume one (1959), see pages 100 and 101 in Vol. 1, No. 4; Volume two (1960), see pages 67 and 68, Vol. 2, No. 6, Industrial Research.

A

adaptive control systems...1:34
aerial platforms 3:52
aeronautics 3:30
agricultural production 5:22
Aiken, Dr. Howard H., director, The Computation Laboratory, Harvard University 2:17
Aircars and the 'Terresphere' 3:52
aircraft 1:14, 24; 2:60
airplane-automobile 3:52
algae 3:23
Allderige, John M., associate professor, College of Engineering, Cornell University (author) 3:57
alloys 1:18, 56; 6:42
aluminum 1:60
amino acids 5:22
artificial islands 3:65
ascorbic acid 5:22
atom-fueled generator 4:78
atomic energy 1:17; 2:24; 3:30; 5:19
Auerbach, Isaac L., president and technical director, Auerbach Electronics Corp. 2:17
automatic transfer machines 2:61
automatic weather station 4:78
automation 1:41, 46, 55; 2:61; 3:33
auxiliary power systems ...4:83

B

Bacon cell 4:21, 22
Basic Approach to Product Development 2:20
Bellman, Dr. Richard E., mathematician, The RAND Corp., consultant, Hughes Aircraft Co....2:18
Bennett, Rear Adm. Rawson, (Ret.), former Chief of Naval Research..2:18
binary systems 1:49; 2:44
biochemical fuel cell 4:23
bioelectronics 1:31; 5:30
Bionic Machines—A Step Toward Robots 1:31
Boolean algebra 2:46
Budenholzer, Dr. R. A., director, American Power Conference; professor, Illinois Institute of Technology 6:29
bored tunnel 3:44
Brunetti, Dr. Cledo, president, Grand Central Rocket Co. 2:18
building block principle....2:61

C

Camras, Marvin, senior engineer, Electronics Research Div., Armour Research Foundation 2:18
Can You Afford Government R&D Contracts? 5:13
carbohydrates 5:24
catalysts 1:36; 2:23
cement failure 3:66
ceramic cutting tools 2:62
cesium generators 4:54
charge transfer machines..4:75
chemical propellants 4:74
chemistry 1:14; 5:22
Clarke, Arthur C., scientist, novelist (author) 5:30
closed-circuit environment 3:23
closed-circuit TV 4:32
close-spaced diodes....4:53, 81
clue words 2:43, 45
cold machining 2:62
columbium 6:42
combustion methods 1:66
communications satellite...1:16
communications systems 1:19, 31, 43
Composite Molecular Electronics 3:26
computer:
analog 1:18, 32, 58
components ...1:56; 3:24; 5:38
digital ...1:32, 40, 48, 58; 5:14
computer simulation:
systems 1:42; 2:61; 3:23
space environment 2:21; 3:23
computerization ...2:34, 41, 44, 57, 60; 5:31
conductivity 1:58; 4:57, 60
continuous seismic profiler 3:47
contouring systems 2:60
The Controversial Gas Turbine 6:29
correlation analysis 3:60
corrosion 1:14; 4:30
Crompton, Dr. Charles E., director of nuclear chemistry, The Martin Co. (author) 4:78
cryogenic memory 1:60
cryotrons 6:44
cybernetics 1:31; 2:37; 5:35

D

Danilov, Victor J., I·R editorial consultant (author) 1:13
data processing...1:40; 2:33, 41, 44; 4:72; 5:14
defense contracts ...1:13; 5:13; 6:14, 20
deForest, Dr. Lee 2:18, 33
Denholm, Dr. A. Stuart, manager of power conversion, Goodrich-High Voltage Astronautics Inc. (author) 4:70
H. S. Denison 5:15; 6:33
depressurization 3:20
design theory 3:57
destructive tests 1:66
De Zubay, Dr. Egon A., project director, fuels research, Atlantic Research Corp. (author)..4:19
dietary requirements 5:24
diversification planning ...2:53
documentation 2:37, 48
double-skeleton catalyst (DSK) 4:26
dry-film lubrication 4:76
dust fuel reactor 4:58

E

eddy current 1:65; 4:58
Editorial Advisory Board....2:17
Education Machines—A Trend Toward Automated Teaching 1:46
electrical generators ...4:72, 78
electrochemistry 4:19
electroluminescence 1:19
electrolytic machining 2:63
electromagnetic devices 3:26; 4:70
electron-beam process 2:63
electronic brain 5:31
electronics 1:55; 2:24, 64; 3:24, 31
electrospark machining 2:63
electrostatic generation 1:17; 4:70
Electrostatic Power for Spacecraft 4:70
energy conversion ...1:17; 4:19, 28, 50, 56, 62, 70, 78
engineering:
design 3:57; 5:57
education 5:56
recruitment 3:63; 5:19
shortage 5:52
The English Channel Tunnel: 159 Years of Research 3:41
Everitt, Dr. William L., Dean, College of Engineering, University of Illinois 2:19
The Evolutionary Cycle from Man to Machine....5:30
exothermic reduction 6:47
exotic fuels 4:24
exotic metals 2:62
explosive metal forming....2:63

F

fatty acids 5:23
feedback 1:48; 2:43
ferroelectrics 1:60
ferromagnetics 1:59
food production....1:15; 5:22
food supplements 5:23
fossil fuels 4:26, 69; 5:19
frictional induction machines 4:70
Fuel Cells 4:19
fuel cell devices..3:29; 4:19, 30
Functional Electronic Block (FEB) 3:24

G

gallium arsenide 1:59
galvanic corrosion 4:30
Garvey, Edward J., manufacturing research director, General Products Div., IBM Corp. (author) 4:36
gas turbine:
engines 6:29, 45
generators 6:34
germanium transistors 1:59; 4:32
government research 1:13, 31, 50; 3:19, 26, 52; 4:19, 28, 51, 63, 71; 5:13, 25, 54; 6:14, 21
government R&D spending....1:13; 5:14, 38, 54; 6:16, 21
Green, Dr. W. B., section manager, Semiconductor Dept., Westinghouse Electric Corp. (author) 4:28
ground-effects machines (GEM) 3:48, 52

H

heat exchanger-regenerator ...6:32
heat pumps 4:30
heat sink 4:30, 72
heat-transfer techniques...4:54
Herndon, Dr. L. Kermit, vice-president, Energy Div., Olin Mathieson Chemical Corp. 2:19
Higgins, Dr. Thomas J., professor of electrical engineering, University of Wisconsin 2:19
high-altitude chamber 3:20
Hirsch, Marx, president, Molybdenum Corp. of America (author) 6:43
Hodges, Luther H., Secretary of Commerce (author) 6:22
hot box detector....5:15
hot cell facility....4:81
hot machining 2:62
hovercraft 3:54
How to Get Government Contracts ...6:14
human-factors engineers 1:48; 5:33
hydrofoil ships...1:19; 5:39; 6:33
hydrolysis 5:24
hydrothermal synthesis ...1:58
Hyperion effluent outfall...3:46
hypersonic space gliders...1:16
hypersonic wind tunnels...1:18

I

immersed tube tunnel....3:44
indium phosphide 1:59
Industrial Applications of the Exotic Metal, Columbium 6:42
Information Retrieval (a special section)....2:33-48
information retrieval systems 1:42, 59; 2:33, 41, 44; 3:59
infrared instruments..1:59; 5:14
Introducing I·R's Editorial Advisory Board 2:17
ion engines 4:44, 74
ion-exchange cells....4:22
The I·R 1961 Forecast: $14-Billion for Research..1:13
irradiated foods 1:17
Isotopic Power 4:78
isotopic power generators..4:79

J

jet engines 6:29, 49

K

Kaye, Dr. Joseph, late president, Joseph Kaye & Co. (author)....4:50
Kelly, Dr. Peter M., staff scientist, Aeronutronic Div., Ford Motor Co. (author)....1:31

L

laboratory controls 2:24
laminated materials 1:60
Language Engineering 2:44
language instruction booths 1:51
lead sulfide 1:59
Levacar 1:19; 3:52
life support systems....3:19
literature search 2:33
Living in Space....3:19
Long, H. Dale, president, ASTME and Scully-Jones Co. (author) 2:59
lubrication 4:69, 76
luminescent materials 1:58

M

Machines and Decisions (a special section)....1:31-52
machine translation 2:48
magnetic triodes 4:54

magnetohydrodynamic (MHD) systems.....1:17; 3:29; 4:30, 56
Magnetohydrodynamics ...4:56
magnetostrictive material..3:25
Management Machines—A Systems Approach.....1:40
Mandell, Melvin, I•R contributing editor (author) 5:13
manufacturing processes 4:34; 5:26
manufacturing research 2:59; 5:37
materials research..1:25, 58, 65; 3:33; 4:54, 74
mathematical programing 2:62; 3:60
McPherson, Dr. Archibald T., associate director, National Bureau of Standards (author) 5:20
mercury turbines 4:63
metallography 1:66
metallurgy 1:14, 65; 2:59; 3:31; 6:46
microcircuitry 1:19
microminiaturization 1:32; 5:32, 55
microorganisms 5:27
microwave communication..1:19
miniaturization ..1:56; 4:78; 5:55
missiles 1:14, 16; 5:55
Modigliani, Dr. Piero (author) 1:70
modules 2:61
The Molectronics Engineer—A New Species.....3:24
molecular engineering 1:55; 3:24
monitoring and control devices 2:62
moon base.....1:13; 3:22
Moore, Dr. Charles H., technical director, Copper Products Development Assn. (author) 2:20
motivation of scientists....3:64
multi-aspect indexing 2:45
Murdock, J. W., information research and operations, Battelle Memorial Institute (author) 2:41
Myatt, DeWitt O., president, Science Communication Inc. 2:19

N

Nablo, Dr. Sam V., manager, electrical propulsion, Goodrich-High Voltage Astronautics Inc. (author) 4:70
navigational light buoy....4:78
neurons 1:31; 5:32
A New Dimension in Manufacturing Research 5:36
New Materials for Electronics 1:56
Noble, Harrell V., electronic technology laboratory, Wright Air Development Div. (author) 3:24
nondestructive tests 1:65
nuclear fuels 4:69
nuclear power generation 4:58, 78; 6:35
nuclear reactors...1:17; 4:31, 79
nuclear submarine....1:17; 4:24
nucleic acids 1:18
numerical control systems 2:60
nutrition 5:22

O

objective formula design...3:59
obsolescence 2:65; 5:55
Oman, Henry, research specialist, Aero-Space Div., The Boeing Co. (author) 4:62
open environmental system 3:21
organoleptics 5:27
oxygen recovery system....3:23

P

Packer, Dr. R. E., senior training systems analyst, General Dynamics Corp. (author) 1:46
paraboloidal solar concentrator 4:66
particle accelerators and analyzers 4:76
passive detection systems..5:15
patent legislation 5:18
perceptron 1:31
PERT system 5:55
Peter, Dr. Rolf W., manager, Electron Devices Div., Watkins-Johnson Co. (author) 1:56
petroleum 1:14; 5:25
pharmaceuticals 1:15
photochemical reactions...4:21
photoconductors 1:58
photoelectronic devices.....1:19, 59; 2:37
photosynthesis 1:17
photovoltaic principles.....1:60
piggyback-railroad twin tunnel 3:41
piston engines 6:30
Pitfalls of Information Retrieval 2:33
plasma physics..1:17; 4:54; 6:23
plastics 1:19
Polish prefix notations.....2:45
polymer science 5:27
polypropylene 1:19
positioning systems 2:60
Practical Information Handling 2:41
product development..2:21; 5:37
project selection 3:64
propulsion systems 4:72
proteins 5:24

Q

qualitative information approach 2:41
Quiet Revolution in Metalworking 2:59

R

Race, Robert W., supervisor, Techno-Economics Research, Armour Research Foundation (author) 2:53
radar 1:31
radiation 1:16; 3:21
radioactive heat sources 4:78, 83
radioactive waste 1:17
radio astronomy 1:18
radioisotope heat sources..4:80
reading machines....1:18; 5:14
Realistic Research Administration 3:62
reciprocating engines 6:30
reconnaissance satellites.....1:13, 16; 4:80
refractory materials...1:60; 6:42
reliability.....3:20, 26, 60; 4:30, 69, 78; 5:55
repeatable acoustic seismic source (Rass)....3:47
research:
applied...1:14; 2:21; 5:53; 6:21
basic.....1:14; 2:21; 6:21
budget....1:13; 3:62; 5:13, 52; 6:21
capability 6:15
organization 3:66
proposals 6:17
trends 1:15
Research and Money.....1:70
Rice, Harold W., director of research, Western research center, Robertshaw-Fulton Controls Co. (author).....3:62
robots 1:31; 5:35
rockets 1:16; 4:72, 74
Rowe, Dr. Alan J., manager, industrial dynamics research, Hughes Aircraft Co. (author) 1:40
rubber 1:19
Ruzic, Neil P., I•R editor & publisher (author) 3:41

S

satellites.....1:16; 4:64, 78, 80
N. S. Savannah.....1:17
Scientific Sleuthing with a Metallurgist.....1:64
sea power plant.....6:38
search request 2:46
sea thermal energy conversion 6:37
sea water corrosion.....4:83
selenium 1:59
Semarne, H. M., research programing coordinator, Douglas Aircraft Co. Inc. (author) 2:44
semi-closed environmental system....3:22
semiconductors 1:32, 59; 2:24; 3:24; 4:28, 80
sensing devices 4:78
servomechanisms 1:31
Shapley, Dr. Harlow, former director, Harvard College Observatory, Harvard University 2:19
Sharp, Harold S., technical librarian, AC Spark Plug Div., General Motors Corp. (author) 2:33
Should the Government Back More Basic Research? 6:22
Shultz, Dr. Eugene B., Jr., manager, energy conversion, Institute of Gas Technology (author) 4:19
silicon 1:59; 4:64
silicon solar cells...4:21, 63, 80
silver iron telluride.....1:59
Simon, Maj. Gen. Leslie E. (Ret.), staff director of research, The Carborundum Co. (author) 5:52
Simpson, G. S. Jr., information research and operations, Battelle Memorial Institute (author) 2:41
Sleight, Dr. Robert B., president, Applied Psychology Corp. (author) 3:52
SNAP generator 4:78
Sodha, Dr. Mahendra Singh, senior physicist, Armour Research Foundation (author) 4:56
solar:
cells.....1:19; 4:31, 64, 78
collectors 4:26
concentrators 4:63
energy 1:60; 4:63; 6:37
flares 1:18; 3:21
telescope 1:18
Solar Machines in Space...4:62
solid fuels 4:19
solid state devices.....1:55; 3:24; 4:31; 5:38
sonar 1:32; 3:47
space programs.....1:15, 16; 3:19, 22; 4:74
space technology.....1:15; 3:19; 4:20, 28, 51, 63, 71, 78
spectrographic analysis ...1:65
The Spectrum Theory of organizing Research and Engineering 5:52
standards and calibration..6:23
static power generation....4:51
statistical language manipulation 2:42
statistical methodology 5:57
steam turbogenerators.4:20, 57; 6:34
Steele, Dr. Theodore K., executive vice-president, Bulova Research & Development Laboratories (author) 6:15
Stirling-cycle engines 4:63
strain-gage analysis 1:66
stress analysis 1:66
strontium-90 .....4:81
sunspots 1:18
superalloys 1:18
superconductors 1:60
survival suit 4:32
Snyder, Asa E., vice-president, Pratt & Whitney Co. Inc. (author) 6:37
symbolic logic technique...2:44
synchrophasitron 1:17
synchrotron 1:17
synthesis.....1:17, 57; 5:22
The Synthesis of Food.....5:20
synthetic organic chemistry 5:27

T

Taussig, Leonard, director, Taussig Associates (author) 1:64
teaching machine 1:46
technical conferences 5:19
technical management 1:40; 2:20; 3:62; 5:54; 6:23
technical manpower 5:58
telecommunications...1:14; 5:35
telemetering equipment....4:78
thermal difference belt.....6:38
thermal energy.....4:28, 57, 81; 6:37
Thermal Energy of the Sea.....6:37
thermionic devices..1:60; 3:29; 4:51, 63, 67, 80
Thermionics 4:50
thermionic-thermoelectric combined units 4:31
thermocouples....1:60; 4:28, 67
thermoelectric cooling 1:60; 4:28
thermoelectric devices....4:20, 28, 66, 78, 83
thermoelectric research....1:19, 23, 60; 2:29; 4:28, 51
Thermoelectricity 4:28
Toward a Theory of Design 3:57
transistors 1:19; 4:32
truth-matrix analysis.....2:46
turbofan engines.....6:30
turboshaft engines.....6:33
Tuve, Dr. Merle A., director Carnegie Institution 2:19
two-propositional functors 2:45

U

ultra-low temperature machining 2:63
ultrasonic machining 2:63
underdeveloped countries..6:37

V

vaccines 1:18
vacuum tubes.....1:59; 4:70, 80
Van de Graaff electron accelerator 4:71
variable area nozzle principle 6:33
variable capacitance machines 4:75
Venn diagrams 2:44
vitamins 5:22

W

walking barge 3:46
waste heat 4:30, 69
Watson-Watt, Sir Robert, governing director, Sir Robert Watson-Watt and Partners Ltd. 2:74
weapons systems 1:31
weather satellites..1:13, 16; 4:78
Welsh, Dr. John A., president, Flow Laboratories Inc. (author) 4:50
Whisenhunt, G. B. Jr., lead engineer, Vought Astronautics Div., Chance Vought Corp. (author) 3:19
Why Diversify? 2:53
Williams, Dr. Clyde E., president, Clyde Williams & Co. 2:74

X

x-rays 1:65

Z

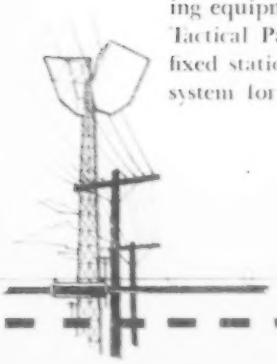
zero-gravity environment...4:69
Zworykin, Dr. Vladimir K., honorary vice-president, Radio Corp. of America...2:74

Putting the Air Force "in business"—anywhere

Today, the Air Force can fly a complete communications center into any remote area and set it up in the field for immediate use. This is made possible by the AN/FCC-17 multiplexing equipment, shown above in its 60-channel Tactical Package, but also expandable in its fixed station version to a 600-channel carrier system for microwave radio.

A highly sophisticated system, the AN/FCC-17 could be created only by a leading specialist in video, voice and data transmission systems. It is further proof of Lenkurt Electric's mastery in designing, developing and manufacturing quality communication systems of advanced design and proven performance.

Lenkurt Electric Co., Inc., San Carlos, Cal.



LENKURT ELECTRIC

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

Specialists in VIDEO, VOICE and DATA TRANSMISSION

INDUSTRIAL RESEARCH
BEVERLY SHORES,
INDIANA

MRS P M COLLING, ED
UNIVERSITY MICRO FILMS
313 NO 1ST ST
ANN ARBOR MICH

BULK RATE
U. S. POSTAGE
PAID
AURORA, ILLINOIS
Permit No. 1

"SMALL OPPORTUNITIES ARE OFTEN THE BEGINNING OF GREAT ENTERPRISES"

Demosthenes

Given the opportunity, great enterprises can result from the blending of talent, timing, hard work and good fortune — enriched with creative capital. But, there are as many kinds of capital as there are opportunities, and it is important to choose wisely.

American Research and Development Corporation specializes in creative capital. We at ARD continually seek investment opportunities in scientifically oriented companies, where our capital and specialized services can be employed to build projects into businesses of stature and importance.

ARD, the first publicly-owned venture capital investment company in the nation, has helped others take advantage of their opportunities for more than fifteen years.

We invite you to bring to our attention your project or your company. If you would like to know more about how ARD can help finance your company or project, please write for our brochure, "CREATIVE CAPITAL."

AMERICAN RESEARCH AND DEVELOPMENT CORPORATION
The John Hancock Building, 200 Berkeley St., Boston 16, Mass. HAncock 6-7060

Creative capital for building businesses along the technological spectrum